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INSET DRAWING—Hydroplane "Bluebird."

CULTURE AND THE SCIENCE MUSEUM

Museums come to be associated in all our minds either with times past or places distant. At the Science Museum in London, for example—a museum somewhat misnamed, since it is as much concerned with technology as with science—the history of the development of countless devices can be traced and there is an unrivalled collection of historic objects, some of which come from distant places. Museums also come to be associated in our minds with "learning" and "learned" people. True, at the Science Museum there are handles that can be turned to "make the wheels go round," panoramic pictures and other exhibits designed to appeal to the less fully instructed. But the basic task is assumed to be that of providing as much detailed authentic material as possible about past developments, in particular for the use of people already well-versed and well-read in the history. Far be it from us to suggest for one moment that this conception of the function of the Museum is wrong. There is no finer collection in the world, nor anywhere is there a more reliable or more detailed collation of the known facts. What we have to suggest is that to this task of the Museum there should be allied another.

Just across the road from the Science Museum there stands the Victoria and Albert Museum. Those who visit it need no esoteric knowledge of the artistic accomplishments of many countries to enjoy and appreciate what is placed before them. That museum, indeed, is a model of restraint in making no parade of the wealth of knowledge that has gone into its arrangement. But at the Science Museum much that is on view is far less easy to appreciate ; nor do the descriptive notices, couched often in technical language, go far to help the uninitiated. Yet we confess we cannot really see that very much can be done by mere alteration of descriptive notices. For it is hopeless, from the start, to suppose that a casual visitor can be quickly initiated into and made to appreciate the more highly technical developments. The appeal of descriptive notices must in the main be to the man with at least a good groundwork of technical knowledge about the objects he seeks to examine. Yet, just as museums of art, like the Victoria and Albert, exert an influence upon our general culture, so surely ought such a museum as that of Science at South Kensington to bring home to visitors the cultural influence of science and technology upon our developing civilisation. Unfortunately, however, any emphasis upon this cultural aspect is conspicuously absent, although, here and there, no doubt, the Director would be able to instance exhibits having some bearing upon it.

An example of what might be done is not lacking. In Chicago there is a museum which consciously sets out to preach to visitors how much they owe in living their lives to the past and present works of scientists and engineers. One particular exhibit sticks in our memory ; it shows "in the round" the same room in the same farmhouse at four different dates separated by twenty-five years, and demonstrates very clearly how the lives of the inhabitants have been changed within the space of three generations. But that atmosphere permeates the museum. The whole museum is laid out and arranged to create it. Constantly a visitor is reminded that the objects on view have influenced and continue to influence his activities and to colour his thinking, and that a knowledge of them is an essential part of his twentieth century culture. Archæologists, in laying bare the past, identify cultures by the things men made and the tools they used. For the things men made and the tools they used reveal the kind of life they led. That is as true to-day as it was a thousand years ago, and nearly all the things we now make owe something to our technological knowledge, and all the tools we use are designed in the light of that knowledge. Cannot the Science Museum, without giving up any of its interest in the history of technology, also begin to impress upon its visitors the cultural influence of technology ? Thereby it would give a helping hand to the engineering and other technological institutions which have realised that if this nation is to maintain its place in the van of technological progress a higher proportion of young men must be persuaded to take up a technology as a career.

DIESEL RAILWAY TRACTION

The wide introduction of diesel traction on British Railways continues to be a topic of much interest and not a little controversy. The present shortage of fuel oil has undoubtedly strengthened the case of those who feel that diesels, as an intermediate stage between steam and full electrification, are unwise and unnecessary; but apart from any questions of major policy, the commercial and technical interests involved in the Modernisation Plan are so diverse that any treatise or paper concerned with diesel experience is at once a focus point for operators, manufacturers, research men and publicists alike. Consequently, it was no surprise when a paper by Mr. T. F. B. Simpson, "Diesel Locomotive Building and Maintenance," read before the Institution of Locomotive Engineers a few weeks ago produced an almost record attendance. As works manager of the Derby Locomotive Works, London Midland Region, Mr. Simpson has had a lengthy experience with the various forms of six-coupled shunting locomotives already in extensive use; this experience has since the end of World War II been extended to include the first main line diesel-electric locomotives to run in this country, and more recently still to the new railcars. Although most of the paper was concerned with the experience gained with shunting locomotives, the very nature of the duties performed by such units, particularly in fully mechanised hump marshalling yards, is productive of an outlook on maintenance problems that aims at very high utilisation, and a servicing routine that aims to prevent failures altogether, rather than to deal with them when they occur. Certainly, the main interest of Mr. Simpson's paper lay in the maintenance organisation for all forms of diesel power that is being built up on British Railways. In construction, the railway shops are, for the most part, concerned with the erection of purchased components, large and small, from the complete engine and generators downwards.

Having in mind the difficulties in maintenance that have been experienced with steam locomotives in recent years, and the delays in traffic that have arisen through unserviced engines being sent out to work fast and heavy duties, there were many who felt it was tempting providence to substitute a form of motive power so much more susceptible to maintenance conditions. But it is happily evident from Mr. Simpson's paper that the whole question of maintenance for the diesels is being tackled from an entirely fresh angle. At the main works shops are being laid out on the most modern lines and stationary testing facilities are being installed, while long years of experience with steam are being brought effectively into play to avoid the risk of the new power being built too light, or too delicate to withstand the rigours of day-to-day railway service. But it is not only in the main works that maintenance routine is of the highest importance with diesels. One of the special attractions of this modern form of railway motive power is its high availability; to take full advantage of this there is no doubt that many long and complicated turns of duty will be scheduled, especially for the main line passenger and freight locomotives. It is the accepted aim for them to be away from their home stations for six days out of seven, and if reliability in traffic is to be ensured, the routine servicing, laid down to a close schedule based on the needs of preventive maintenance, must be carried out without fail on the days when the locomotive is on the shed. It is evident from Mr. Simpson's paper that the authorities are fully alive to the needs of the situation; it is no less important that comparable standards of workmanship, care and vigilance in checking, and, above all, of discipline, should be established in all the shops and motive power depots concerned. The go-as-you-please practices, which, despite all efforts to the contrary, have grown up in later steam days, will not do.

The human aspects of diesel maintenance were touched upon during the discussion on Mr. Simpson's paper, and one speaker in particular stressed the desirability of allocating the new power in such a way as to dispense with steam entirely in certain specified areas. This, it was argued, would give all concerned with the diesels a better chance. But it is, we fear, an ideal rather than a practical proposition. If the maximum utilisation is to be obtained from the diesels it is essential for all units on the stud to be employed to their maximum availability. There would be very little power in reserve on the shed. Against this, however, one must set the extreme fluctuations of traffic on British Railways. The secondary lines of the North Eastern Region, north and east of York, provide a case in point. It would be possible to devise satisfactory working diagrams for all the mid-week passenger services to be operated by multiple-unit diesel-electric trains; but on Saturdays in the summer the passenger mileage run is more than doubled. Unless a number of diesel units are idle for six days in the week additional power would have to be brought in. Hitherto, the regular stud of steam passenger locomotives has been strengthened at weekends by many mixed traffic units, mainly employed in goods service; but for some time to come reinforcement for the diesels will have to come from steam, and facilities for servicing steam locomotives retained at coastal termini such as Scarborough. The co-existence of steam and diesel power is a factor that will have to be reckoned with, and especial care taken to keep shed facilities separate, and the highest standards of cleanliness in operation where the diesels are concerned.

THERMAL INSULATION BY COMPULSION

Amongst Private Members Bills which have recently been read a second time is one brought in by Mr. Nabarro and others "to make provision for the thermal insulation of industrial buildings; and for purposes connected therewith." Engineering firms would be well advised to obtain copies of this short Bill since it appears not improbable that it may be accepted by the Government. The purpose of the Bill is to require that all new industrial buildings in which fuel is consumed for the purpose of space heating shall be thermally insulated; and that after an appointed day about four years after the Bill becomes an Act its provisions should apply to old as well as to new industrial buildings.

There is no doubt that the insulation of many factory buildings can lead to substantial economies in the amount of fuel used for space heating. Depending upon the nature of the structure and its use, up to 50 per cent savings can be recovered and obviously upon grounds of national advantage it is desirable to conserve fuel. The question remains, however, whether this saving should be attained by legal compulsion or whether individual firms should be encouraged by the economic merits of so doing to insulate buildings. The argument for legal compulsion, of course, is that in relation to total costs the savings accruing to a firm from the capital expenditure upon insulation often approach the negligible; to serve the national advantage therefore it is necessary to make it a matter of law. For our part we think that the Bill might be acceptable if it were confined to new buildings subject, however, to the amendment that it should be the Factory Inspectorate and not the local authority, as laid down in the Bill, which should be responsible for enforcement. But the application of the Bill to existing factories is more objectionable. It is one thing to incorporate insulation into a building during erection. It is quite another to require it to be applied to a building that is already in use, particularly should the alteration interfere with production. Where old buildings are concerned it is surely better to rely upon economic circumstances, particularly the tendency of the cost of fuel to rise, to convince firms that insulation would be to their advantage. Should the Government adopt the measure it will be desirable for industry to examine the Bill in greater detail, in particular to ensure that its provisions will not apply to buildings the insulation of which would be of little advantage.

A Seven Day Journal

Institution of Naval Architects

THE spring meeting of the Institution of Naval Architects opened on Tuesday morning, March 26, and the annual dinner was held in the evening of the same day at Grosvenor House, London. About 1100 members and their guests attended the dinner, with Viscount Runciman of Doxford, the president, in the chair. Admiral of the Fleet Earl Mountbatten of Burma, the First Sea Lord and Chief of Naval Staff, proposed the toast of "The Institution of Naval Architects," and broadly outlined certain wartime naval developments before going on to discuss modern trends. These, he said, included the problems of the high-speed submarine and guided missiles, and he believed in having a large number of small ships with an aircraft carrier as the only large unit. He mentioned a new design of destroyer to carry some of the new weapons and the need, through consideration of space, to carry the minimum crew, which implied manning with highly trained personnel. Turning to research matters, the First Sea Lord suggested one or two problems for early solution and went on to deplore the tendency to indulge in research for research's sake; it was essential, he said, to stop at some particular stage in development and go into production. He concluded his remarks with references to the new committee dealing with nuclear propulsion, and expressed the view that the future of the Merchant Navy was closely linked with this form of power. In his response, Viscount Runciman briefly referred to the opening of the meeting, and had a word to say about the work of the Institution, which was to assess and apply results rather than to conduct research. However, he stressed that a primary object in the design of a ship was that it should be safe, and went on to draw particular attention to life-saving methods and regulations; he also made a plea for the use of simple language and the avoidance of complicated descriptions. Sir Wilfrid Ayre proposed the toast of "The Guests," coupled with the name of His Excellency Sir Eric Harrison, the High Commissioner for the Commonwealth of Australia, who, in the course of his reply, referred to the development of shipbuilding and marine engineering in Australia, largely based on the technical skill of men from Great Britain.

Second Stage of the Neath By-pass

MR. HAROLD WATKINSON, Minister of Transport and Civil Aviation, has announced that constructional work will start immediately on the second part of the Neath By-pass, in South Wales. The first part of this scheme, from Briton Ferry to Earlswood, was built during the years 1949 to 1955. The second part of the by-pass will run north-westward from Earlswood for 2½ miles over a network of roads, railways and waterways to Lonlas, where it will join A.48, the existing route to West Wales, at a large roundabout. The scheme provides for twin 22ft carriageways separated by an 8ft central reservation. Earthworks are on a considerable scale. About 300,000 cubic yards will be excavated from cuttings and foundations and the consolidated embankments will require some 500,000 cubic yards, the excess being obtained from neighbouring waste dumps. The carriageway foundations will be in broken stone, 12in thick, laid in two layers, each 4½in thick, after compaction and topped by a 3in binding course. Surfacing will be laid in two coats, a 2½in tarmacadam base course and a 1½in bituminous macadam surface coat. A single 2in layer of hot-rolled asphalt will be laid on the bridges, of which there will be seven. A 22ft span reinforced concrete bridge will be constructed through the embankment between Earlswood and Red Jacket Pill. The Pill itself, a tidal inlet, will be crossed by a three-span prestressed concrete bridge, 140ft in length. A 680ft long viaduct with ten spans will be built over the Rhondda and Swansea Bay Railway, the Tennant Canal and the Vale of Neath Railway; it will have a steel superstructure with a reinforced concrete deck. A skew three-span girder bridge some 125ft long will be built over the Jersey Marine Loop railway, and a 270ft long steel girder bridge in three spans over the Swansea District Railway and Burrows Road. Crymlyn Road will be carried over the new highway by a four-span bridge some 100ft long consisting of six steel portal frames and connecting members, all of welded construction. The main London, Fishguard and Swansea District lines will be bridged at Lonlas in three skew spans by a steel girder bridge 300ft in length. The total cost of the project, including acquisition of land, is estimated to be £1,742,000. The consulting engineers are Messrs. Rendel, Palmer and Tritton, and the main contractor is the Cleveland Bridge and Engineering Company, Ltd.

The Engineer
100 Years Ago
(MARCH 27, 1857)

"EXHIBITIONS OF INVENTIONS"

"The ninth annual exhibition of inventions of the Society of Arts was opened to the public on Monday last. In another column will be found a notice of some of the chief novelties in the mechanical and manufacturing arts which have been brought to light during the past year. . . . There are many persons who would either from want of sufficient concentrative power or from dislike to investigate mechanical or other inventions, allow the most curious invention to pass unnoticed, except it be brought before them in the palpable shape of a model which they can turn round, or a specimen which they can take in their hands and examine. To such persons as these, exhibitions like those got up by the Society of Arts become absolutely necessary, if inventions are to be at all generally understood.

"We may, doubtless, attribute the success in this instance partly to the very favourable locality in which the Society of Arts exhibition is held. . . . It may be that, when the collection of patented inventions shall have been established some little time, we shall get more accustomed to the neighbourhood of Kensington, but at present, whenever we are referred there as a place easy of access, in order to examine a model or any thing else, it fairly makes us gulp—we cannot swallow it. It is like a giant pill which we know will do us good if we can only get it down, but for the life of us we cannot do so. . . . If there is one spot on the whole face of the globe where you can feel that you are within a stone's throw of everybody and everything, that spot is, to our minds, Charing-cross. It lies between the slavery of business on the one hand, and extreme idleness on the other, and if business is to be done in the neighbourhood of Charing-cross, we can always do it and take our pleasure at the same time. We therefore earnestly recommend all those who are interested in the progress of invention to carefully examine the collection in the Adelphi."

Gold Medal of the Institution of Locomotive Engineers

THE council of the Institution of Locomotive Engineers has awarded the gold medal of the institution to Sir William Stanier, F.R.S., for his "outstanding and meritorious service in the advancement of locomotive engineering." This medal was first awarded in 1946 and, as the institution's highest award, is made at the discretion of the council. Sir William has had a long and distinguished career in connection with the railways of this country. He served his apprenticeship at the Swindon works of the Great Western Railway Company, with which he remained for some forty years up till 1931. His last nine years with that company were as the principal assistant to the chief mechanical engineer. When he left the G.W.R. in 1931 he became chief mechanical engineer to the London Midland and Scottish Railway Company, an office which he held until his retirement in 1944. Whilst he was with the L.M.S. Sir William was responsible for many noteworthy developments in the design and construction of locomotives. To all concerned with railways his name immediately calls to mind a number of outstanding engines—the "Princess Royal," the 4–6–0 mixed traffic L.M.S. engines, the "Coronation" class 4–6–2s, and the famous class "8F" 2–8–0 freight tender engines, which many regard as his finest design. During the second world war Sir William served as scientific adviser to the Ministry of Aircraft Production, and later the Ministry of Supply; and he has held many other offices of importance during his career. Sir William became an F.R.S. in 1944, and was president of the Institution of Mechanical Engineers in 1941.

Mr. J. W. Elliott

IT is with regret that we record the death of John Wilson Elliott which occurred suddenly on March 20, in his seventy-first year. Mr. Elliott, who was born on December 9, 1886, was educated at Rutherford College, Newcastle upon Tyne, and entered the shipbuilding firm of Swan, Hunter and Wigham Richardson, Ltd., more than fifty years ago. He remained continuously in the service of the company, becoming secretary in 1931 and being appointed to the board seven years later. After serving as vice-chairman for two years, from 1947, he was appointed chairman of the company, a position which he continued to occupy until his death. He was also chairman of the Wallsend Slipway and Engineering Company, Ltd., The Hopemount Shipping Company, Ltd., M. W. Swinburne and Sons, Ltd., and Titan Cranes, Ltd., and in addition was a director of Barclay Curle and Co., Ltd., The Glasgow Iron and Steel Company, Ltd., The National Shipbuilders Security, Ltd. and the Shipbuilding Corporation, Ltd. For two years, from October, 1953, Mr. Elliott served as President of the Shipbuilding Conference and, in October last year, he was elected chairman of the British Shipbuilding Research Association. For his services to shipbuilding, Mr. Elliott was appointed a C.B.E. in 1951 and in 1956, on board the liner "Bergensfjord," was invested as a Commander of the Royal Order of St. Olav, by H.R.H. The Crown Prince Olav of Norway.

The Hydroplane "Bluebird"

By L. H. NORRIS, A.M.I.Mech.E., and K. W. NORRIS, B.Sc.(Eng.), A.C.G.I., A.F.R.Ae.S.

The configuration of Mr. Donald Campbell's "Bluebird" differs considerably from earlier high-speed craft. Here an account is given of the reasons why this solution was adopted by the consultants responsible for the boat's design, Norris Brothers, Ltd., Burgess Hill. The article contains an explanation of the principal problems met with in the design of the "Bluebird" and of how they were overcome. Details of the craft are shown in the inset drawing facing page 478.

BEFORE going into the details of the design of "Bluebird," it would perhaps be appropriate to make a few brief comments on previous high-speed craft. The last two water speed record holders have been driven by piston engines through a water-immersed propeller, the configuration being based on the three-point suspension principle, two planing surfaces forward and one aft. In the case of the earlier record holder "Bluebird," the aft planing surface was provided by the under surface of the transom, and for "Slo-Mo-Shun," the late American record holder, by the propeller blades, the planing trim of the craft lying approximately through the propeller boss. The lower efficiency of the propeller with this arrangement, is more than offset by the much reduced drag, the shaft and supporting brackets being clear of the water surface. Craft operating on this principle are termed "prop riders."

The earlier record holders "Bluebird" and "Slo-Mo-Shun" were similar in shape, the major areas in plan view being forward,

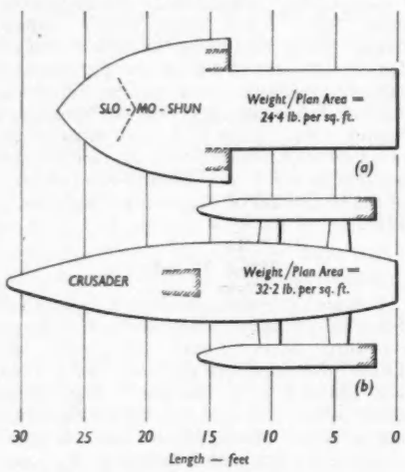


Fig. 1—Characteristic hydroplane shapes

as shown in Fig. 1(*a*). This shape, characteristic of all previous three-point hydroplanes has severe aerodynamic limitations. The aerodynamic lift is of large magnitude, this being accentuated by efforts to reduce frontal area, resulting in a flat-shaped hull with high lift characteristics, critical to incidence. As the centre of this lift is forward of the centre of gravity, a tendency to pitch up results. Considering the case where the craft hinges back about the point of contact of the rear planing surface with the water, we find that as speed increases the upward lift force moment can become greater than the downward weight moment of the craft. Overturning backwards results. This actually happened in the Gold Cup race with "Slo-Mo-Shun," which flipped back and performed a complete loop, carrying on minus pilot. It was presumably to overcome this limitation that the jet-propelled three-point hydroplane "Crusader," Fig. 1(*b*) was designed, with two planing surfaces aft and one forward, this configuration allowing the air-lift overturning moment about the aft planing surface to be much reduced, if not obviating it altogether, by moving the centre of pressure aft of the C.G.

Three Classes of Water Craft

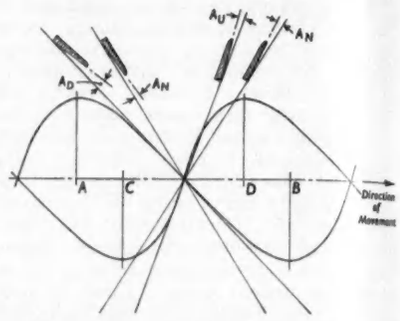
In view of the above, it is perhaps worth clarifying here one reason why high-speed water craft are in fact water craft and not aircraft and hence why water speed records cannot be won by aircraft trailing a protruberance through the water. Boats which by definition are water-borne vessels, may for convenience be divided into three classes. (1) Low-speed water craft usually of the displacement type where water forces predominate and air forces are negligible ; (2) high-speed water craft usually of the planing type where water and air forces are of the same order ; (3) high-speed water craft which eventually take to the air due to the predominance of air forces.

Class 1 craft are stabilised by water forces. Class 2 craft must of necessity, under normal operating conditions pass through a phase corresponding to Class 1 and having reached Class 2 because of shape limitations must still rely on water forces for stabilisation, air forces being unstabilising.

Class 3 craft which must normally pass through phases corresponding to classes 1 and 2, contain those craft which are really Class 2 craft travelling beyond their safe top speed and can "fly as well as a brick" and aircraft such as flying boats which are merely using water as a means for take off. The latter having no special shape limitations can be made to fly in a stable manner by arranging that the aerodynamic centre (point at which the air forces may be represented by a direct lift/drag force and by a constant moment) is aft of the C.G. This requires a special aerodynamic lifting surface such as a tailplane. The regulations relating to water-speed records, however, bar the use of special aerodynamic lifting surfaces and hence so restrict the shape of potential record craft that to fly in a stable manner is impossible and such craft must therefore for safety remain in one of the true boat Classes 1 and 2.

Water Screw Problems

So far as known to the authors all propeller-driven craft with a speed in excess of about 150 m.p.h. have operated on the "prop riding" principle and for any high-speed craft this or an equivalent technique would need to be adopted. To keep the propeller r.p.m. within reasonable mechanical bounds, a relatively long pitch propeller must be used, this being more sensitive to shaft angle. This shaft angle, the effect of which is shown in Fig. 2, is necessary, as all shaft driving gear must be clear of the water. It is assumed, with these high-speed propellers that the blade is in a stalled or cavitated condition on the back surface; therefore no streamlining is adopted, the blade being wedge-section to provide maximum strength with minimum angle on the leading edge of the blade. The material thickness should preferably be contained within the slip angle, minus the shaft angle of the blade, or interference will take place on the back surface on the upward moving blade side.



A_N = Incidence angle to mean helical path.
A_D = Incidence angle to actual path of downward moving blade.
A_U = Incidence angle to actual path of upward moving blade.
All above conditions are for blade in horizontal position and for 15 deg. shaft angle.
A-B = Distance covered by downward moving blade per half rev.
C-D = Distance covered by upward moving blade per half rev.

Fig. 2—Paths followed by points on each blade due to 15 deg. shaft angle

Unfortunately, for craft with a potential speed of 200 m.p.h. or more, the difficulty is to promote "prop riding" at the right speed, i.e. to prevent the propeller producing too much lift in the low-speed range, a condition which produces a corkscrew pitching movement. As the propeller rises too far out of the water it loses bite, the r.p.m. rise, forward speed is reduced, the stern drops in the water and the cycle recommences.

One of the major factors affecting propeller lift for a given shaft angle and propeller diameter is pitch. The longer the pitch the greater the unbalanced lift forces on the blade, due to the higher ratio of the shaft angle to the pitch or helix angle. The other main source of lift is due to "free surface effect," the water presenting greater resistance to the downward travelling blade. This effect increases with pitch and for speeds below the designed speed of the blade.

To reduce this lift force, the blade is given "lay back," i.e. the radius of generation of the helix is laid back at an angle of less than 90 deg. to the propeller axis. There is a great deal yet to learn about the application of this technique and it does not necessarily mean that there is a "lay back" angle which will balance out the lift to the desired amount for any propeller. Indeed, indications have been very much the other way. The crux of the problem then, is this. To limit shaft speeds, the propeller pitch must be increased to a point where propeller lift is difficult, if not impossible to control throughout the speed range. To help offset this, the C.G. of the craft must be brought aft—this in direct opposition to the requirements for aerodynamic safety. Furthermore the efficiency of the propeller, after it has met all these other design limitations, is relatively low, 50 per cent being considered as the highest likely figure for a propeller designed with the existing available information and shaft arrangement, and 25 per cent being a more probable one.

The foregoing has been mentioned, as it will enable the reader to appreciate decisions made during the evolution of the design of the new "Bluebird."

Initial Layout

The authors were originally approached by Mr. D. M. Campbell to provide a general

arrangement drawing of a racing craft with which he could attempt to bring back the Harmsworth Trophy to this country from the present American holder. A configuration was laid out for a crew of two, in compliance with the regulations governing the race. This configuration was much the same as for the final design, the forward planing surfaces being mounted on outriggers, but the hull shape was such as to be aerodynamically safe for a top speed of approximately 200 m.p.h.

Model Tests

An eighth-scale model was made and experiments were conducted in the towing tank. The model was towed at speeds corresponding to Froude number for full-scale speeds below 70 m.p.h., the drag was measured and stability characteristics were observed. Particular attention was paid to the transitional period from the displacement to planing condition. This transition recorded a total drag peak of approximately 2000 lb and the spray patterns were acceptable, keeping clear of the main hull. The towing tank carriage had a maximum speed of 40ft per second and it was therefore decided that more information on the high-speed characteristics would have to be obtained from self-propelled model experiments.

The model was dynamically corrected and provided with a hydrogen-peroxide rocket engine. Experiments were conducted over a wide expanse of inland water, control being effected electronically. Throughout the tests, data were obtained through visual observation and photographic recording.

Initial runs were of short duration, being designed to check the transitional period from displacement to planing and to enable spray patterns to be accurately observed and recorded.

The second series dealt with stability in disturbed water and runs were made both across- and down-wind, the response to waves ½in to 1½in high model-scale being considered very good.

The third series concerned rudder trials. A tapering-wedge dagger-plate rudder was used, mounted on the transom. Response was very satisfactory and this suggested that there was no immediate purpose to be served by the evolution of a different rudder shape or position.

The final trials dealt with maximum performance and stability. The runs were recorded photographically and cinematographically and timing was carried out with synchronised stop watches over a 100-yard course. The maximum speed recorded was 78 m.p.h.

Using the following relationships (which assume resistance mainly due to wave making)

$$\text{Weight of model} = \frac{\text{Corresponding full-scale weight}}{\text{Scale}^3}$$

$$\text{Thrust of model} = \frac{\text{Corresponding full-scale thrust}}{\text{Scale}^3}$$

$$\text{Speed of model} = \frac{\text{Corresponding full-scale speed}}{\sqrt{\text{Scale}}}$$

the following figures were obtained :

	Model, actual	Full scale
A.U.W., lb, ...	9·00	4600
Thrust lb effective ...	5·80	2970
Thrust/A.U.W.	0·645lb/lb	0·645lb/lb
Speed, m.p.h.	79	221

These figures appeared quite acceptable. Furthermore the model had shown no tendency to pitching oscillation and porpoising at high speed.

A combination of tank and free-running model test results, plus the information obtained in the wind tunnel (see below), enabled the performance curves shown in Fig. 3 to be obtained.

Change of Policy

While this model testing was under way, Mr. Campbell decided that, for personal reasons, it would be preferable to attack the world water-speed record.

For a craft to compete for the water-speed record the control must be hydrodynamic, no aerodynamic control surfaces being permitted. The craft must complete a run each way through the measured mile or kilometre within an hour and the average speed of the two runs must exceed the speed of the existing record by 0·75 per cent. The crew need comprise one person only.

The speed required would be in the region of 200 m.p.h., and so bearing in mind the aforesaid remarks on prop riding and the

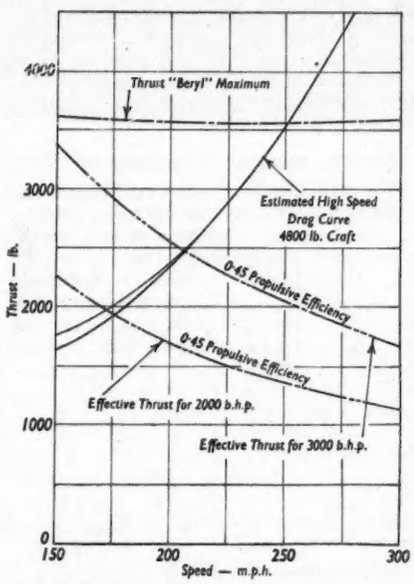


Fig. 3—Available thrusts for screw and gas turbine propulsion

thrust curves, Fig. 4, the natural choice of power units fell to the jet engine.

The Ministry of Supply, through the co-operation of the manufacturer, Metropolitan-Vickers Electrical Company, Ltd., agreed to provide two "Beryl" turbo-jet engines for this project, and a third was lent by the College of Aeronautics, Cranfield.

The "Beryl" is a jet unit of straight-through design, incorporating a ten-stage axial-flow compressor, a single annular combustion chamber and a single-stage turbine. The leading particulars are as follows :

Static thrust	3850 lb
Overall length	12ft 2in
Diameter bare engine	37·25in
A.U.W.	1850 lb

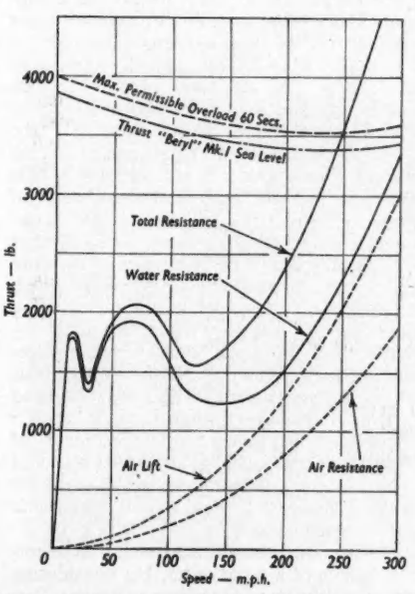


Fig. 4—Estimated performance at 4800 lb powered by "Beryl" MK1 engine

Theoretical Performance Calculations

The resistance of high-speed planing craft is not fully covered by known or proved theory. This resistance may be broken down as follows :

R1 ...	Form drag due to planing lift only	Water drag on supporting planes and directional control surfaces
R2 ...	Skin friction resistance	
R3 ...	Wave or spray forming drag other than *R1* above	
R4 ...	Spray impingement drag, i.e. spray from forward-surface impringing on after-surface of hull	
R5 ...	Form drag	Aerodynamic drag.
R6 ...	Skin friction drag	
R7 ...	Induced drag	

R1.—May be determined with reasonable accuracy for small angles α of attack on the planing surface and total waterborne weight W, being a simple resolution of forces which may be expressed $R1 = W \cdot \tan \alpha$.

R2.—Presents a much more complex problem. No tested and reliable information is publicly available on friction characteristics at these speeds and the flow pattern is indeterminate.

R3.—Again is impossible to determine theoretically with reasonable accuracy.

R4.—It was hoped to avoid *R4* altogether with correct layout.

R5, *R6*, *R7*.—May be adequately dealt with by standard wind tunnel technique.

This leaves only *R2* and *R3* as unknown. Here model tests were of great assistance, but extrapolation of model results particularly in the case of *R2* is impossible with any certainty as we do not know a reliable method of finding the variation of the skin friction with speed and could not visualise running model tests at full speed. The deduction made earlier on the model results must be viewed in this light.

Whilst these factors were unknown however, a much more practical method of determining the minimum likely top speed was possible though not perhaps with exactitude. Information was available for "Slo-Mo-Shun" the earlier "Bluebird" and "Crusader" as to the weight of craft, power and speed obtained. "Crusader" would have provided almost direct comparison but for the fact that the craft probably never attained its ultimate speed. "Slo-Mo-Shun," however, was considered more suitable and by making the following assumptions, speed for a comparable craft was calculated.

1.—Maximum possible overall propulsion efficiency of 45 per cent.

2.—Overall resistance increased as speed squared (this was decidedly pessimistic).

3.—Resistance for a given craft will be directly proportional to weight, i.e.

where available thrusts $= T_1$ and T_2 respectively,

relative weights $= W_1$ and W_2 respectively,

and maximum speeds $= V_1$ and V_2 respectively,

then

$$\frac{T_1}{T_2} \times \frac{W_2}{W_1} = \frac{V_1^2}{V_2^2}$$

$$V_2^2 = \frac{T_2 \times W_1 \times V_1^2}{T_1 W_2}$$

$$V_2 = V_1 \left(\frac{T_2}{T_1} \times \frac{W_1}{W_2} \right)^{\frac{1}{2}} \quad \ldots\ldots (1)$$

From Fig. 3 maximum thrust available to "Slo-Mo-Shun" at 178 m.p.h. = 1900 lb. The weight projected for "Bluebird" was

the same for " Slo-Mo-Shun " substituted in (1).

$$V_2 = 178\left(\frac{3550}{1900}\right)^{\frac{1}{2}}$$

$$= 245 \text{ m.p.h.}$$

A further performance calculation based on wind tunnel test results in conjunction with N.A.C.A. data, produced maximum speeds of 240 m.p.h. and 288 m.p.h. respectively for hydrodynamic drag over lift ratio of 0·15 which was thought to be a practical value and 0·08 which was a theoretical value.

General Design

A more detailed design of craft suitable for the installation of the "Beryl" engine was commenced in January 1954. The main requirement was to bring back the aerodynamic C.P. still further and reduce lift generally. It was realised that this was in direct contrast to the requirements for the low speed condition prior to planing, as reduction of air lift surface forward also means a reduction of water lift surface forward, with the danger that favouring the aerodynamic requirement too much would result in the craft not rising to the planing condition. The line was drawn, however, on the side of high-speed safety, as it was considered possible, with the aid of " steps " and " flow directors," to ensure planing with a much reduced forward surface.

Wind Tunnel Testing

As soon as the configuration was decided, an eighth-scale model was made and tested in the wind tunnel during February. The 5ft by 4ft tunnel at the Imperial College of Science and Technology was made available. Mr. P. T. Fink, of the University Aeronautics Department, generally looked after the running of the tests.

Several minor alterations to the general configuration were tried, all concerned with reducing pitching moment and the resulting curves, Fig. 5(*a*) and 5(*b*) were obtained. A great deal of the detailed calculation was undertaken by post-graduate students.

It was not possible to get the C.P. acting through or aft of the C.G. However, the lift was of low magnitude and, as will be noted, the craft appeared to have ample margin of safety at 5 deg. pitch angle at speeds up to 250 m.p.h.

It will be appreciated that although the craft would therefore be aerodynamically unstable statically in pitch, i.e. any upward pitching would result in increasing aerodynamic pitching moment, the craft was still aerodynamically - hydrodynamically stable statically, as the same upward pitching would result in much less hydrodynamic lift forward.

Low-Speed Spray Considerations

The general design work therefore proceeded and meantime water towing tests were carried out with the same model to see whether the craft would come up to the planing condition. Planing occurred at the equivalent full-scale speed of about 40 m.p.h., but the spray conditions up to this speed range generally, and particularly at about 5 m.p.h., were not too satisfactory. It was considered necessary to build a somewhat bigger model to determine low-speed characteristics fully, but this was precluded by time and finance. These troubles had to be overcome in full scale. It would be as well to mention at this point that high-speed, free-running model trials were not considered necessary for this revised configuration, as the disposition of the planing surfaces C.G., &c., were virtually the same as for the earlier two-seater configuration.

Dynamic Stability

The main barrier to higher speeds on water appears to centre around dynamic stability. Under certain conditions the water can present a disturbing force of the same frequency as either the natural fore and aft pitching frequency or the rolling frequency of the craft, and unless suitable damping is available a divergent oscillation commences, resulting in the destruction of the craft. This had already appeared to happen in the case of the late Sir John Cobb's craft. To get some idea of the conditions likely to be met, an investigation was carried out on the last eight seconds of " Crusader's" final run, which terminated in disaster. A film was obtained which had been taken with a telephoto lens from some long distance away, such that the craft was virtually at right angles to the camera throughout. A suitable datum line was taken on the craft and the change of angle of this line, relative to the water surface, was plotted, frame by frame, together with the displacement of a point of the nose above water. These readings were plotted, a section of the resulting curve being reproduced in Fig. 6. Whereas it was only hoped to obtain some idea of pitching frequency, correlation was found between this and nose displacement. The curves indicated a main frequency of approximately 4 to 5 c/s with a superimposed ripple frequency of 10 to 12 c/s and a change of trim of plus and minus 1½ deg. Bearing in mind the craft length of some 31ft, these were figures which caused much concern.

Further analysis showed vertical acceleration figures of a large order, but considering the relatively poor time-base of twenty-four frames per second, these were viewed as inaccurate and are therefore not given here. What did appear evident, however, was the fact that special precautions would be required if the new " Bluebird " were to survive such conditions.

Having assumed that adequate thrust is available, impact loading due to disturbed water, and the stability of the craft generally require the utmost consideration. As already mentioned, disturbances occurring at the natural pitching frequency of the craft if allowed to continue, would result in oscillation of a large magnitude. This could possibly culminate in a nose-dive or, if the air lift is large in magnitude, a flip backwards. Large external disturbances, however, are not necessary for oscillations to occur either in pitch or roll. With reference to Fig. 7, if we consider a minor increase in drag ΔD, at the forward planing surface this provides a nose down pitching moment of $\Delta D \times h$, where h is the height to the C.G., from the planing surface.

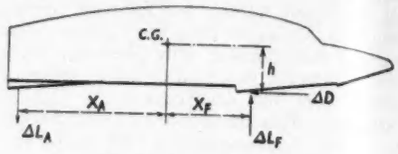


Fig. 7—Dynamic Stability

The resultant nose-in is counteracted by increasing lift ΔL_F on the forward planes and decreasing lift ΔL_A on the aft plane and the craft is pitched back by the moments $\Delta L_F \times X_F$ plus $\Delta L_A \times X_A$.

Unless the damping effects cause greater loss of energy than the energy fed into the system by $\Delta D \times h$ then an unstable condition arises. Whereas the matter is considerably more involved than is indicated, it may be stated that for a given sudden increase in drag the disturbing moment is proportional to the height of the C.G. of the craft and the restoring moment is dependent on the horizontal distance between the C.P., the planing surfaces and the pitching centre and on the change in lift with depth of immersion. This latter is dependent on speed, angle of incidence and length-width ratio of the planing surfaces, and represents the " spring rate " which, together with the pitching moment of inertia, determines the natural frequency.

As no information was available to the author about the behaviour of planing surfaces at the high speeds contemplated, the following method of approach was used :—

(*a*) The disturbing moment was kept to an absolute minimum by keeping the C.G. as low as possible. This was drastically carried out at the expense of free board for the jet nozzle which was only a few inches in the static condition.

(*b*) The fore and aft position of the planes was adjustable.

(*c*) The planing shoes were removable so that shoes with alternative angles of attack

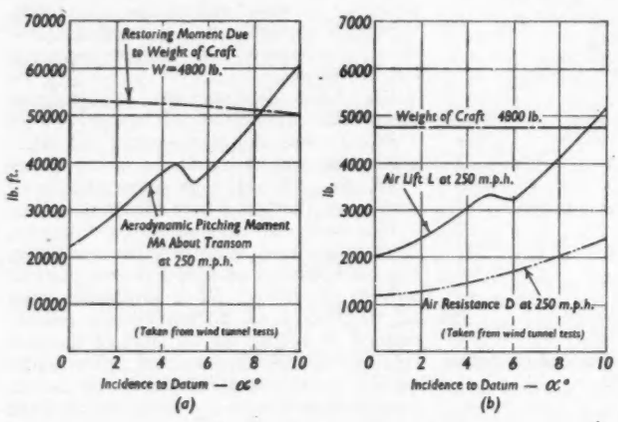

Restoring Moment Due to Weight of Craft W=4800 lb.
Aerodynamic Pitching Moment MA About Transom at 250 m.p.h.
(Taken from wind tunnel tests)
lb. ft.
Incidence to Datum — α°
(a)
Weight of Craft 4800 lb.
Air Lift L at 250 m.p.h.
Air Resistance D at 250 m.p.h.
(Taken from wind tunnel tests)
lb.
Incidence to Datum — α°
(b)

Fig. 5—Wind tunnel curves for pitching

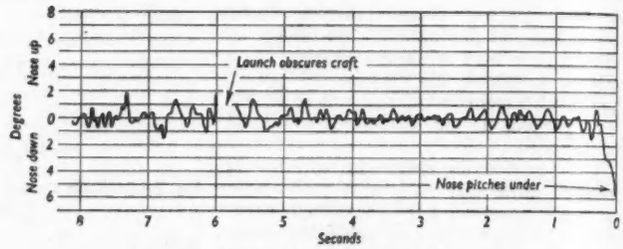


Fig. 6—Analysis of "Crusader's" last run

Fig. 8—"Bluebird" at speed, showing the most recent configuration, with spray deflectors and the "blown" canopy

and planing width could be attached. Alternative angles envisaged for the rear planing surface are shown on the inset drawing.

(*d*) The forward surface of the floats was given a very steep angle of attack having an entirely different lift/immersion depth ratio from the normal planing surface. Only if extremely large oscillations occurred would these forward surfaces become immersed at high speed. They also provided anti-dive surfaces should the craft be pitched forward at such an angle that negative incidence would occur on the normal planing surfaces. In any case, if the angle of these latter surfaces had been continued until the surface was above the normal displacement condition waterline, as is essential, then they would become rather long and cause too much air lift forward. The alternative of a rounded forward surface was unacceptable as at certain attitudes and speeds it could possibly cause suction effects, producing negative lift forward. A further point in favour of the steeply sloping forward surfaces is that they would appear to be the best means of getting lift at low speed coupled with ability to cope with rough water at medium speed.

(*e*) The normal planing surface was given no dead rise as at lower speeds than that contemplated various reports indicated that dead rise tends to cause porpoising.

This method of approach looked after the obvious sources of trouble as well as possible, and provided means to change the configuration in full scale should instability become apparent. Careful full-scale experiment was therefore essential and involved considerable risk. To ensure that the stability characteristics could be accurately determined, instruments were fitted to measure pitch, roll, nose displacement, vertical acceleration and speed, this information being transmitted to a shore base and recorded.

Structure

The main load bearing members of the craft consist of a high-tensile tubular-steel main frame with two transverse spars of high-duty aluminium alloy, continuous through the hull for attachment of the forward planing surfaces. General stiffness was considered to be most important as deflections might have affected the rudder position or possibly prevented actuation of the rudder due to increased control circuit stiffness. Too much deflection could also have resulted in an unacceptable change of incidence of the planing surfaces. The steel frame was manufactured in T 60 2in square section tubing, the gauge thickness varying to suit the load conditions of the various members. "Pick-up" holes for the main spars, engine mountings, rudder brackets, &c., were provided by small round tubes welded into the main square section tube. The frame was made watertight throughout and in the event of sinking had sufficient buoyancy to support more than its own weight. General jointing throughout the frame was by welding, no web plates being used except where required for special load conditions. Stressing was therefore based on the welded condition of the material where appropriate.

The main and forward spars were fabricated from light alloy angle and plate to form a square box-section structure with vertical diaphragms as required. Steel tubing was not used in this particular application, as the depth of these spars critically affected the aerodynamic lift. With the type of construction used a maximum of metal was concentrated at the most effective distance from the neutral axis for a minimum of spar depth. A further consideration was also the ability to make the spars watertight and again self-supporting if immersed in water. These spars are connected to the main frame with HTS bolts and are bolted to the outer planes to facilitate removal for transport.

The planing floats themselves consist of a light-alloy box-section structure totally enclosed and watertight, fabricated from angles and sheeting, the forward anti-dive surface being incorporated in this structure. The main planing shoes are bolted on separately. The fairings are detachable members. The structure is divided with vertical diaphragms, those at either end being somewhat heavier to transfer the vertical punch load from the planing shoe into the spars. These end diaphragms were positioned in such a manner as to provide the alternative pick-up position (see section on "Stability"), in the forward and aft directions for the spars. Solid alloy billets machined out to suit were used for the three planing shoes, the forward two being attached to the floats and the aft one bolted up through the under-surface into the main frame. These

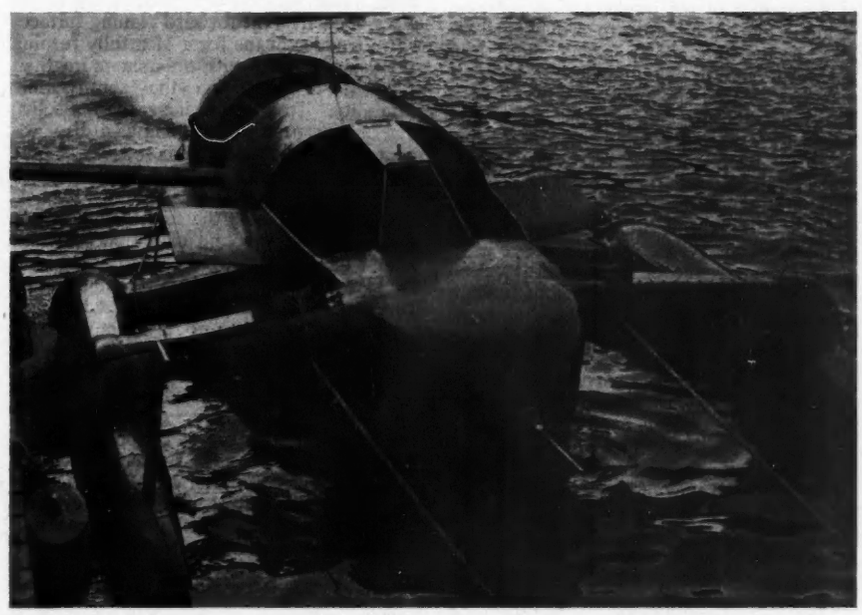


Fig. 9—"Bluebird" before the final modifications were made. The shape of the cockpit cover has since been modified, and the spray deflectors have been altered, as explained in the text

surfaces were stressed to withstand up to 600 lb per square inch, local pressure. To the forward shoes were attached high-tensile steel directional stability fins with countersunk high-tensile steel screws.

The main skin of the craft is in light alloy, being 20 S.W.G. on the top sides, 18 S.W.G. on the lower side surfaces and on the general under-surface 16 S.W.G. This under-surface is reinforced with corrugated light-alloy sheet joined together by rivets. The support for the skin consists of light-alloy cross-panels riveted to steel plates which, in turn, are already welded to the steel frame. This construction allowed even the more complicated sections of the main frame to pass through watertight bulkheads. The steel attachment plates can be clearly seen in the inset drawing. The cross panels are flanged all round to provide the outside profile attachment for the skin. In the course of construction the main frame, complete with panels, then provided a jig for the manufacture of the skin. Where a watertight or fireproof bulkhead is required the cross panels have no lightening holes, thus serving a dual purpose. All skin and panels below the thrust line are permanent, and above it they are removable in two sections. These sections allow access to the engine, but the whole assembly is stress carrying, i.e. the main frame carries the direct vertical acceleration, deceleration and skid loads, but resulting torsional loads are carried by the skin and sub-structure.

Owing to the desirability of keeping the fuel tank at the C.G., and to the very restricted space available, a ring tank with 48 gallons capacity was provided, the air intake passing directly through the centre. The vertical C.G. of such a tank is high but there is the advantage that when the tank is full the fuel pump is primed by the head of fuel.

The air intakes are built into the structure and rivetted throughout except at the leading edges which are radiused back and welded on to the topside skinning which at this point is not removable. The ducting was carefully designed to ensure constant cross-section at all points. Extending forward on either side of the intakes are Perspex spray deflectors to prevent excess of water from entering the intakes. The main surface of these deflectors stands about 4in clear of the hull at the mouth of the intake and is radiused in along the bottom edge to provide attachment to the hull. They extend about 12in behind the mouth of the intakes. The compartment behind the pilot's head forms a streamline fairing between the ducts and houses the electronic equipment, access being provided from the cockpit. The pilot's seat is built into the main framing and the back cushioning is attached to a vertical watertight bulkhead immediately forward of the main spar.

On the underside of the forward section of the hull is a low-speed step from which a planing surface extends forward and upwards at a steep angle. The surface is in 14 S.W.G. light alloy reinforced with transverse corrugations, the space between currugations at the lower sections where impact up to fairly high speed might occur, being tightly packed with wood. On this surface are bolted light-alloy angles shaped to form flow directors. These direct the flow of water straight under the hull to promote maximum water lift at low speed.

No mention has so far been made of the trim tanks which were provided aft. It was anticipated that in the normal displacement condition the craft would sit nose down in the water and that this negative angle of attack would prevent the planing surfaces from bringing the craft up. The trim tanks took the form of a double skin aft and, although the above conditions did arise, the tanks were found to leak through into the main hull and could not be made serviceable. They were therefore removed completely and the hull was reshaped, the loss of buoyancy having a similar though not quite such an efficient effect.

Stressing

The two main cases of loading considered in analysing the structure were for impact under the rear spar and impact under the front spar. The former case corresponded to planing on the main surfaces, the latter to planing on the front preventor surfaces. For the first case, fully factored loads due to accelerations of 27*g* down, 8*g* fore and aft and 4*g* sideways were applied at the C.G., together with air loads and full thrust.

For the second case, the equivalent loading was 18*g* down, 4*g* fore and aft and 2*g* sideways. The sideways or skid load was based on a normal expected side deceleration of 0·5*g* corresponding to a turning circle of 1½ miles at 250 m.p.h. and resulting in a course error of 1 deg. if not corrected within $^{3}/_{5}$ sec.

Steering

From the wind tunnel tests it is quite apparent that the craft aerodynamically is directionally unstable. To overcome this condition aerodynamically would require a large tail fin surface, which unfortunately cannot reasonably be accommodated. Also, it will be appreciated that any under-water surface is liable to severe damage, if coming into contact with a semi-submerged object and it is therefore desirable to keep such surfaces to a minimum. However, extra underwater stabilising surface aft would appear to provide the only practical solution.

The ideal arrangement would be to provide fixed stabilisers aft, well swept back to ride or cut through any obstruction, with a small rudder forward which would carry away under emergency conditions. Unfortunately this would not allow adequate low-speed steering characteristics, which are quite important from the general operational aspect, as the rudder would be too close to the C.G.

The system used therefore consists of small, swept-back stabiliser fins on the inside edges of each of the forward planing surfaces with a rudder in the form of a fully turning stabilising fin aft, with an area more than sufficient to overcome the aerodynamic instability. To allow an increase of effective area at low speed when acting as a displacement craft this rudder was offset to port sufficiently to avoid masking by the central aft planing surface. The rudder load is balanced by bringing the centre of the stock on a line of 20 per cent of the chord width behind the leading edge. In sectional plan the blade is a straight wedge brought back from a slightly radiused leading edge, this latter being necessary to give the requisite stiffness. Unfortunately, in side elevation, the leading edge could not be swept back as is desirable to cope with underwater obstruction as this would have resulted in a fore and aft change in the centre of pressure with depth of immersion. The rudder is machined from a one-piece forging of S.80 steel, fully heat-treated. Control is by a tiller arm coupled to a conventional steering-box and wheel through aircraft control-rods.

Cockpit, Controls and Instrumentation

There are two main controls in the cockpit —the steering wheel and the foot-operated throttle. In addition to the latter there are high- and low-pressure fuel cut-off levers. The instruments are the following :—Air speed indicator ; revolution counter ; fuel pressure gauge ; jet pipe temperature gauge ; g. meter with maximum hand.

The radio control is by simple on-off switches and the operation of starting is conducted from outside, external batteries being used. The starting relays and equipment are mounted on a panel in the engine compartment.

The pilot's seat is padded and incorporates a webbed safety harness. Air breathing is fitted, including an underwater breathing mask. In the event of sinking at slow speed and the pilot being trapped, depending on depth, approximately half an hour's air supply is available. There is a mircophone in the mask.

The cockpit is covered by a blown Perspex sliding canopy with internal and external release catches. A hand-operated wiper is used to clear away any low-speed spray deposited on the forward surface in the line of normal vision. All mating surfaces round the canopy are sealed with rubber against the entry of water.

Full-Scale Trials

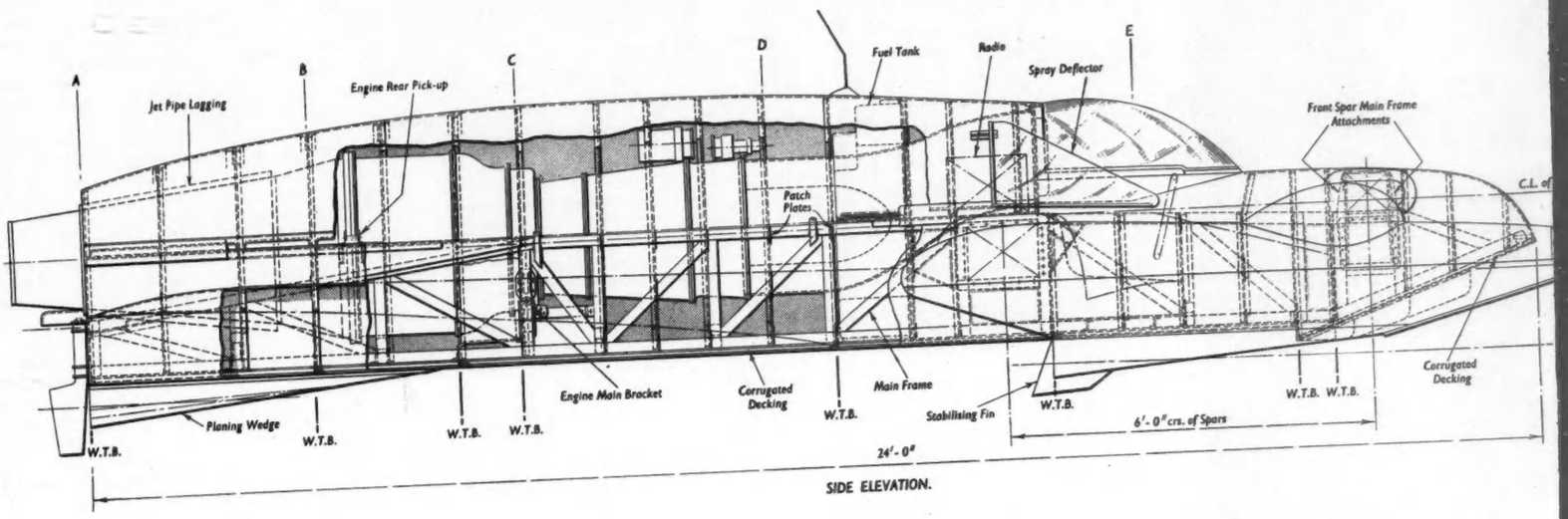
Detail design of the craft started in January, 1954, and she was launched on Ullswater in February, 1955. Full-scale trials were started immediately in spite of adverse weather conditions.

As was anticipated, the craft trimmed nose down. The trim tanks provided to overcome this have already been mentioned. As these trim tanks were unservicable the front spar was brought too near the water surface and appeared to create a suction effect. No flow-directors had been fitted at this stage as it had been decided to develop them on the full-scale craft. In these circumstances, as only the very minimum of lift surface had been provided forward, excessive spray caused engine flame-out before the craft could reach the planing condition. It was decided to bring the craft on to the main planing surfaces to ensure that all was well, and also to check the speed at which this occurred, by means of a low-speed spray-deflector-cum-lift surface which was provided by attaching a metal sheet between the spars. The craft was brought to the planing condition at about 40 m.p.h. and speeds of up to 160 m.p.h. attained. Higher speeds were not attempted as this temporary arrangement produced large aerodynamic overturning moments.

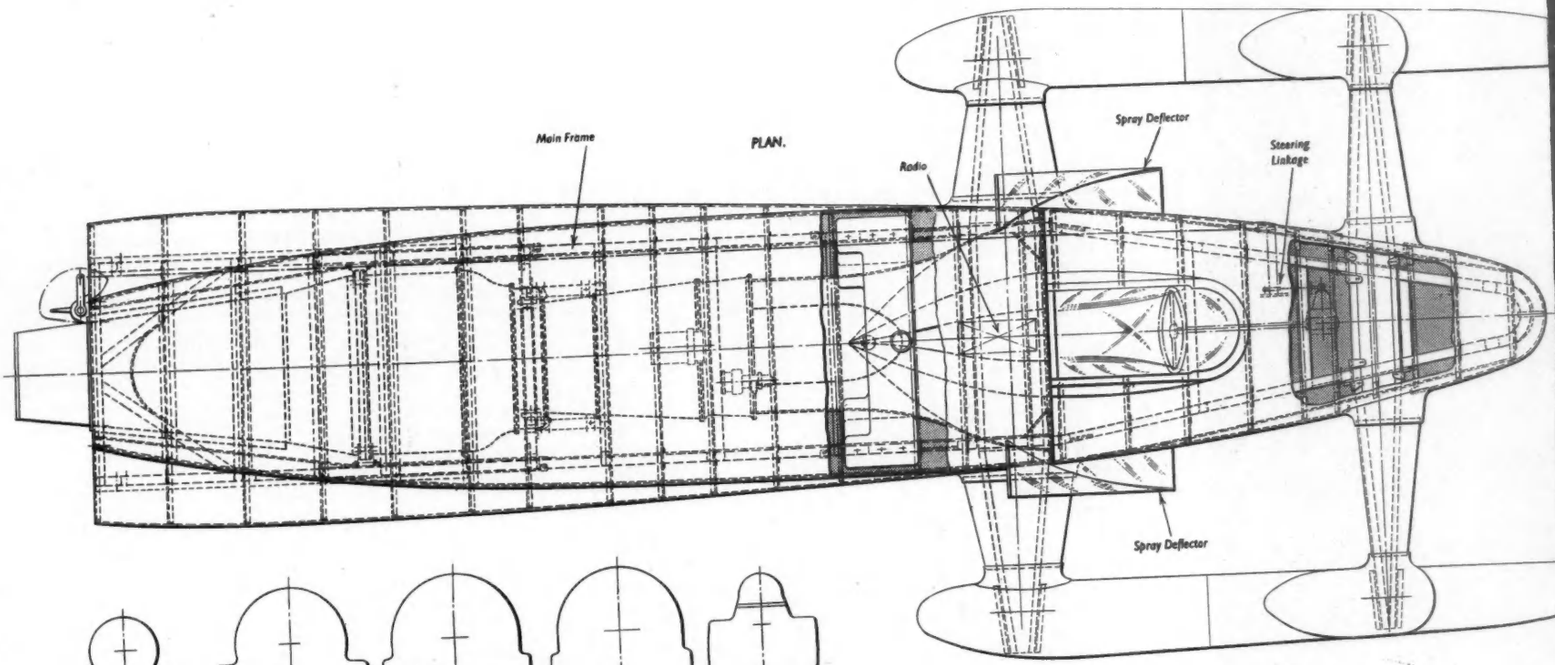
As these trials indicated no likelihood of high-speed troubles, a programme of work was undertaken to remove buoyancy aft, raise the forward spar slightly and fit flow-directors. Wind tunnel tests and low-speed water towing tests to observe spray patterns were carried out on a revised model. These tests were done on a pond with quite crude towing equipment, and cinematography was used to analyse the results. These tests indicated satisfactory low-speed behaviour generally, but a somewhat difficult spray condition was noted around the intakes. Not being able to create the same suction effects as would occur at full scale, it was decided the development of a suitable intake shield should be undertaken full scale. The spar and flow-director modifications only were therefore made to the craft, and in June full-scale trials recommenced.

The model experiments proved to give an extremely reliable indication of full-scale conditions and a suitable intake shield was developed. This was not then completely satisfactory, but has since been developed, as shown on the general arrangement draw-

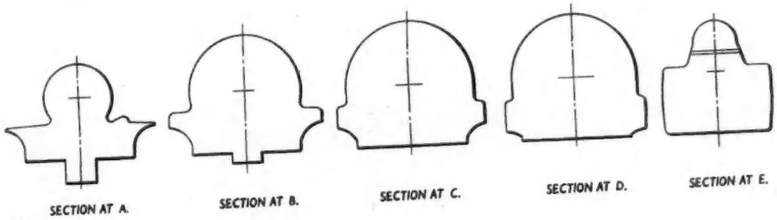
THE HYDROPLANE "BLUEBI



SIDE ELEVATION.



PLAN.



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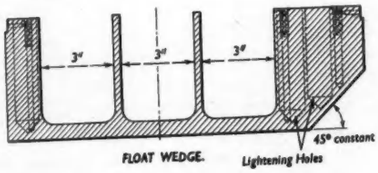
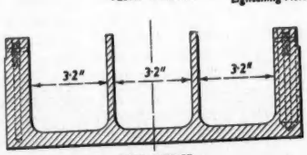
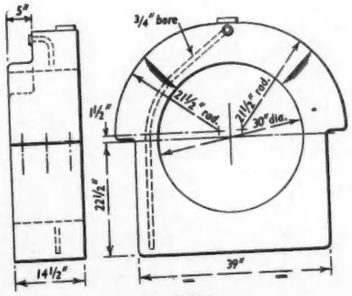


FLOAT WEDGE.

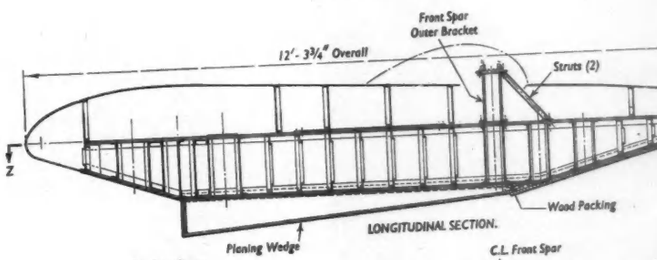


REAR WEDGE.

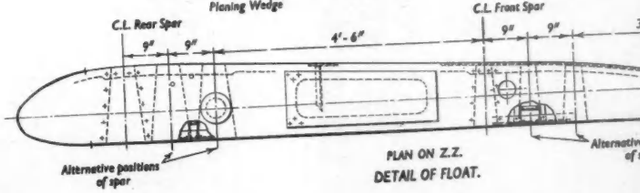
SECTIONS THROUGH PLANING WEDGES.



FUEL TANK.
(Capacity 48 gallons)



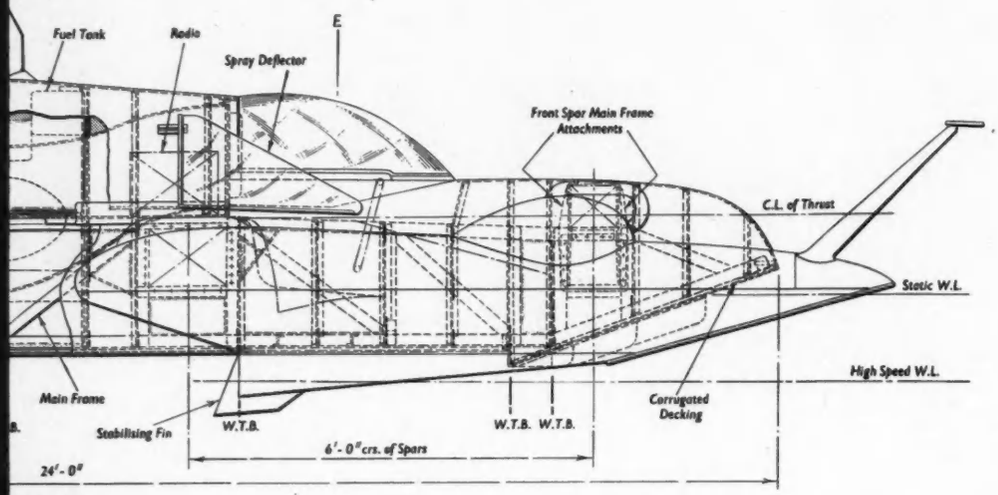
LONGITUDINAL SECTION.



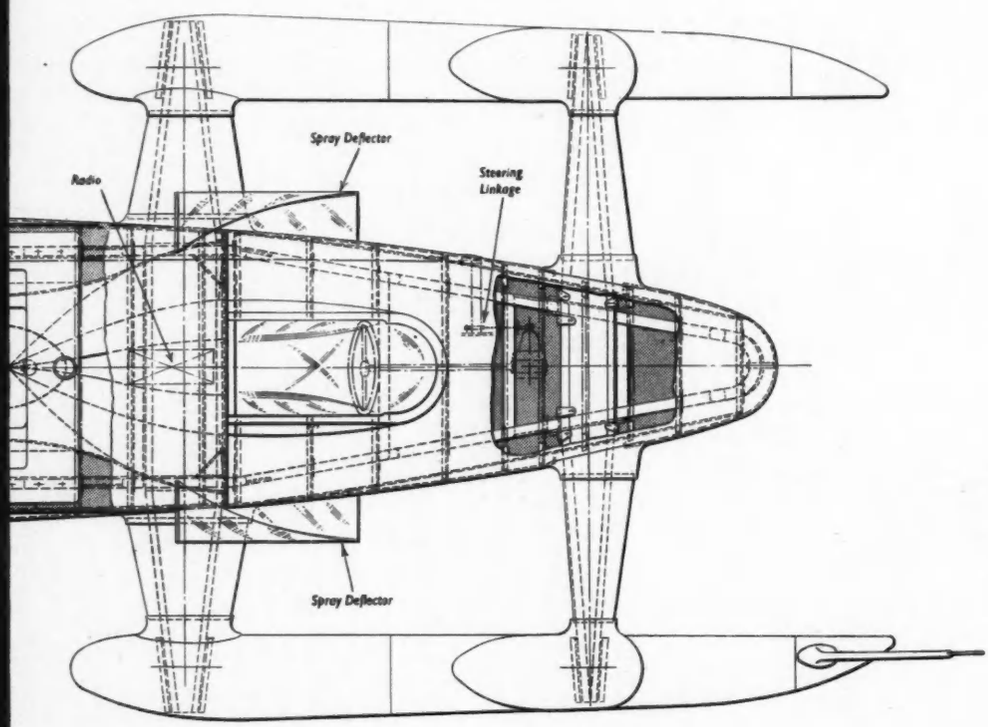
PLAN ON Z.Z.

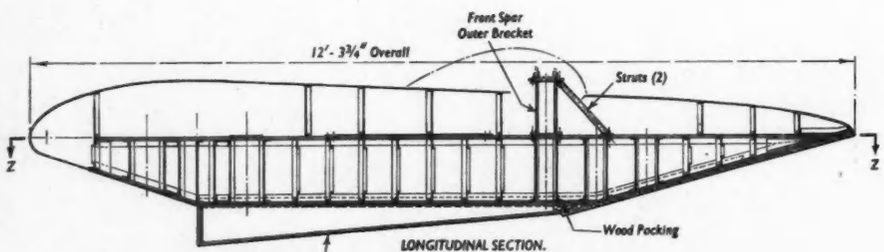
DETAIL OF FLOAT.

THE HYDROPLANE "BLUEBIRD"



ELEVATION.





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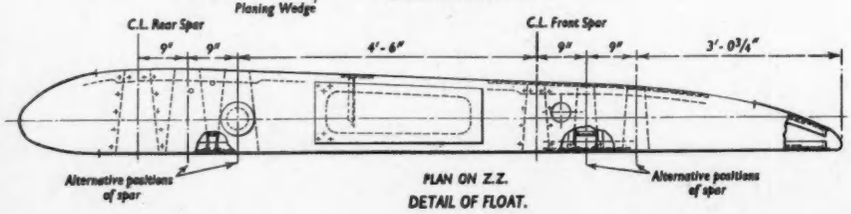
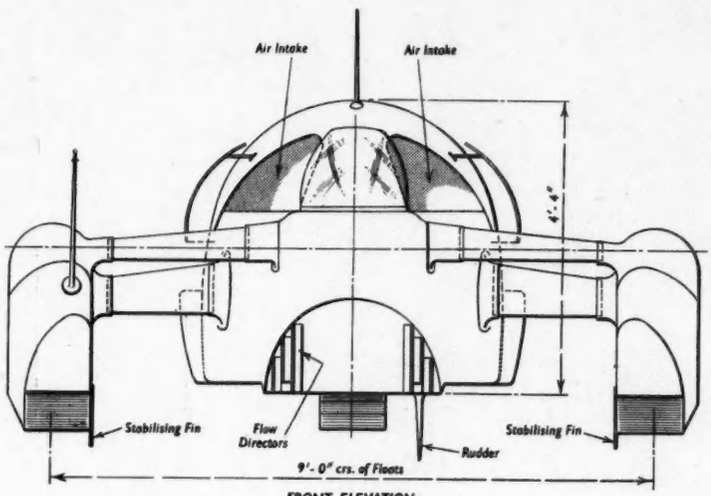
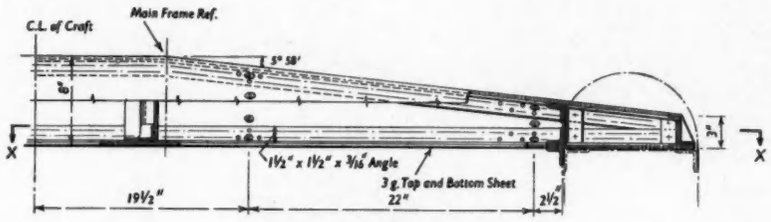


PLAN ON Z.Z.

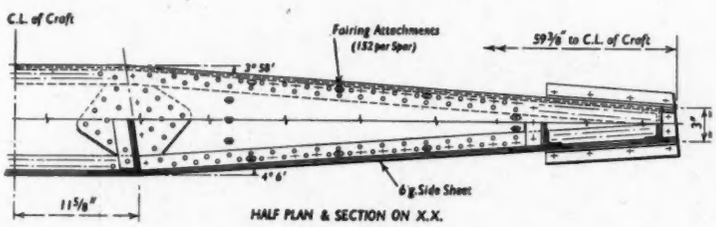
DETAIL OF FLOAT.



FRONT ELEVATION.

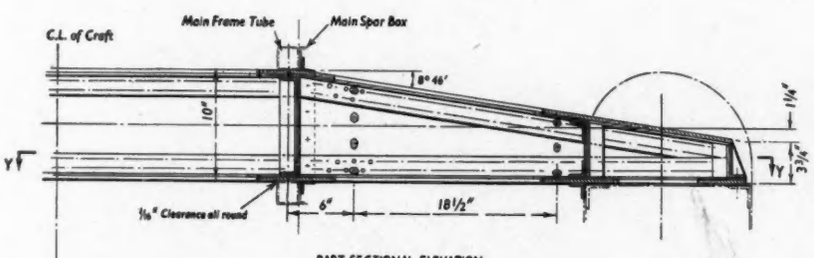


PART SECTIONAL ELEVATION.

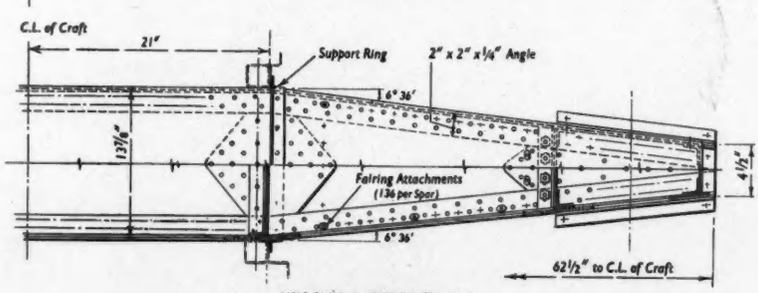


HALF PLAN & SECTION ON X.X.

FRONT SPAR ASSEMBLY.



PART SECTIONAL ELEVATION.



HALF PLAN & SECTION ON Y.Y.

REAR SPAR ASSEMBLY.

ing, so that flame-out due to spray does not occur. The general stability of the craft has been good, very low-frequency pitching having been noted only occasionally and then possibly due to disturbed water conditions. There is sometimes a rapid roll oscillation of small magnitude around 150 m.p.h.

The craft can be brought up to the planing position using approximately half engine thrust, and from this point acceleration is extremely rapid, being of the order of 0·5*g*. If, after coming up to planing trim, the power is reduced, then planing can be maintained down to 30 m.p.h. with very little thrust. If the thrust is cut at high speed the craft will skim for a considerable distance. The steering is very positive and extremely light.

For this reason difficulty was experienced due to over-correction and in an attempt to overcome this the leading edge of the rudder was cut back 0·5in to ensure that the C.P. was behind the rudder pivot centre. The forward stabilising fins were also reduced in area. With these modifications and pilot familiarisation no further difficulties have been experienced. A possible improvement would be a cam gear steering box which would give a much higher gear ratio in the central position and still allow full rudder to be applied for low-speed manœuvring.

Rough water conditions have been met with at speeds of up to 200 m.p.h. and on one occasion the wave of a fairly large lake steamer was negotiated safely at 140 m.p.h. Vertical loadings have been up to 6*g*.

Early running trials were made with an engine intended only for bench testing by the team and pilot, to familiarise them with starting procedure, &c., which was down-rated accordingly. It was decided to use this engine for the low-speed trials owing to the unpredictable nature of the water spray pattern, the two fully rated engines being held in reserve. In point of fact, this engine consumed hundreds of gallons of water and was eventually used for the first record.

The estimated minimum top speed figures have been easily exceeded. No accurate thrust/speed figures are available as the craft

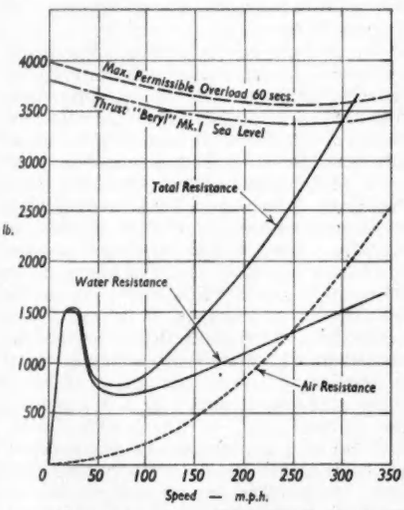


Fig. 10—Probable performance for 5600 lb craft based on full-scale trials

has always been accelerating or decelerating on runs in the high-speed range; Fig. 10 shows the probable maximum performance.

The latest record attempt was made over the kilometre on Lake Coniston on September 19 last. The lake has a usable length of 4½ miles, which allows a run-up of approximately 2 miles at either end. The speeds obtained were 286·78 m.p.h. on the first run, and 164·48 m.p.h. on the return, an average of 225·63 m.p.h.

Scope for Operational Research in Industry

By STAFFORD BEER*

No. II—(*Concluded from page* 437, *March* 22)

On Monday, March 18, *the* 1956 *George Bray Memorial Lecture was presented before the Institution of Production Engineers in the Sheffield City Memorial Hall. We here reprint the opening sections of the lecture and its conclusion. These opening sections describe and comment upon the purposes that operational research can serve, the general principles upon which it is based, and in particular its usefulness to managements. Succeeding sections not printed here dealt with more specific tools than the basic notions here described, and entered into more detail.*

Controlled Estimation.—The need for measurement of an unorthodox kind has been discussed, and an example has been given of a fairly sophisticated indexical technique. The handling of these measurements by methods derived from the theory of probability has been described in terms of establishing a system of description using the notions of maximum likelihood and measured risk. Such a system is flexible; it will not shatter irreparably into fragments in the face of the obstinacy of men, the vicissitudes of production, or the malice of mischance. The system, once set up, can be kept under permanent surveillance by the statistical control of its key elements, the behaviour of which is already understood in probabilistic terms. All this has been illustrated, up to the point of reporting to management, in terms of productivity indices. More positive use can, however, be made of this system: I will give brief descriptions of two such active applications, fuller details of which may be found elsewhere. The first refers to production control (1), and the second to cost accounting (2).

A production control department must produce production plans, and these must involve the creation of detailed machine load programmes. Many production control systems are ineffective because they do not face up to this fact. The reason usually given is that it is impossible, particularly in a jobbing shop, to estimate with any accuracy the time taken to do a given job on a given machine. If really reliable estimates of machine-job times were available for any job on any machine, and especially the class of jobs which have not been done before, then there would be no particular difficulty in constructing a workmanlike production plan. It would be constructed like a mosaic from the component machine-job times. If this plan, in addition to being reliable, were also resilient, then it would not be reduced to chaos as soon as the exigencies of production required its modification.

All these requirements can be met by the active use of a system set up by operational research methods such as that we have been discussing. To estimate a machine-job time, it is necessary first to evaluate the constructed time by exactly those methods described in last week's abstract. The same model and the same notional factors that were used when the system of description was being built are used again. That is, we calculate an objective time. This result has been generated by a model which is known to be isomorphic with the shop floor situation, and the quantitative relationship between the two is measured by the productivity index. Consequently, if we now weight the calculated result by the current index appropriate to the job being considered, we shall reach a statistically guaranteed estimate of the actual time the job can be expected to take.

The details of this procedure cannot be mastered without further and lengthy explanation; but the principle is not difficult, although it is very important. It is widely recognised that there is a difference between theory and practice; this operational approach not only acknowledges this difference, but measures it continuously, and uses the statistically controlled measure (that is, the index) to improve the estimate. Engineers will recognise the principle of "feedback" which is being applied, not mechanically, but statistically.

This method is lively; it is not a static moribund technique which begins well enough and is then left behind by the changing modes of behaviour which characterise the natural evolution of any works. The claim that it will apply to work which has never been done before is justified in the comprehensiveness of our operational definitions. Any occurrence has a statistical probability; this maxim can be applied with great effectiveness to the likelihood of a given job's falling within the ambit of a given model. The resilience of a plan built from components evaluated by these methods is given in their statistical control. For the value taken as an estimate of machine-job time is that determined by the maximum likelihood of its probability function. When these times are built into a machine load, there is a "give-and-take" between successive estimates, also determined by that function. It is as if the bricks with which we are building were set in place, not with a brittle mortar, but with an elastic bond capable of considerable deformation. It is this property in the plan that I call resilience. In practice it provides that the plan can draw out of phase with the production it controls without disintegrating: by taking into account the range of an estimate's variability, the plan acquires what I shall again call the lively quality of adaptability.

This is perhaps the moment to comment on the function of prediction which is a major application of operational research. Planning of any sort is one of those activities in which it would be very useful to know what is going to happen to-morrow, or next week, or next year. In applying itself to this problem, operational research normally uses a statistical technique (such as the one described or the branch of analysis known as Time Series), in which probabilities are examined in their behaviour within an isomorphic model. Now it is woolly thinking of the worst kind to imagine that such a technique will enable management to look into the future; for such a purpose I would as soon use a crystal ball or the entrails of a sheep. If, then, we cannot in fact look into the future, in what sense is the word "prediction" used? Suppose that I put a kettle of cold water on a gas ring. I predict that in a

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few minutes' time steam will issue from the spout, and the water will be boiling. Suppose that I issue cheques to a total value greater than my bank balance. I predict that at some future date I shall receive a message from my bank manager. Each of these examples shows me making an intelligent anticipation of something that has not yet happened ; and yet you will not say that I am gifted with second sight.

Prediction of an intelligent or scientific kind involves induction ; the amassing of particular instances leading to a generalisation which we dignify with the title " law." The extent to which we are prepared to act upon the law depends upon the strength of the evidence which supports it ; we are still in the realm of probability. That the kettle will boil is so likely that people often fail to realise that they are not dealing with a certainty, but with a very high probability. Why is the probability high ? It is because the evidence is simple, clear-cut, extensive, and highly organised. Scientific predictions can be made to the extent that these characteristics are found. The main point of these remarks is this : everything depends upon our discovering the " law," which is the same thing as saying that we have to find a model. The law or the model is the framework within which we organise facts. People sometimes seem puzzled by the readiness with which an operational research man will predict (say) rates of stoppage on production plant, compared with his diffidence in predicting (say) the company's final profit. I would ask them please to remember these basic principles.

The point about cost accounting can now be made quite simply. When an order is received, we want to predict its cost. The modern accountant is well aware of this ; the practice known as " historical costing " is quite out-moded, at least in up-to-date firms. Yet the accountant, like the rest of us, is debarred from looking into the future. Therefore, he has much to gain by invoking operational research. He could fairly expect operational research so to organise his data about raw materials, about overheads and, most of all, about output rates, as to introduce liveliness into the costing system in the same sense as that notion was earlier applied to production control.

In fact, this idea has been tried and proved on quite a large scale insofar as output rates are concerned. These can be generated by operational research techniques in just the same way (moreover, by the self-same system) as the planning predictions were made. Figures supplied for costing purposes on these bases have the following advantages : they can be generated very quickly on an electronic computer or other high-speed calculating machine ; they do not require constant overhaul by the works management, because they can be controlled by the routine statistical methods already installed ; significant departures from the standard or average level are automatically signalled by the statistical control ; above all, they are predictions in the sense described above.

Some Important Comments

Complexity versus Simplicity.—Before leaving this discussion of the basic notions behind operational research, there are three comments on what has already been said that I wish to make with some force. The first concerns the complexity of this approach. Fairly simple language has been used, but operational research has probably emerged as rather a complex subject. Is it too complex ? What about the virtues of simplicity ? It is vital that we face up to these questions and to their answers.

Before anything else can be done, a situation must be described both operationally and dynamically. Since the situations in which we are interested are of great complexity, because they involve machines and men and advanced industrial practice, the operational research model must itself be complex. There simply is no short cut at this point. Unless the model parallels the situation in complexity, it cannot attain to isomorphism and cannot predict. This is not to say that the model must needs be as untidy as the situation; indeed, the virtue of these methods considered as descriptive techniques is that they reduce incommensurable measures to pure numbers ; and they reduce variability, risk, chance and misfortune to a system of probabilities of great neatness. But the complexity of the situation is reflected in the difficulty of the algebra ; it is still there.

From this basis a result is obtained : a solution, a comparison, a prediction. At this point, the point of presentation of results, simplicity becomes the real aim. Everyone knows that results must be expressed as briefly, clearly and simply as possible. And yet managers are constantly irked, often to the point of exasperation, by a failure to observe this rule. It may help if I suggest for your consideration two reasons why I think these troubles arise. One is a severe practical difficulty, and the other is a psychological one. Sufficiently wise management can deal with both.

First, the operational research man is anxious that his conclusions should not be misunderstood. He understands the complications of the subject he has been investigating and inevitably feels that the concise answer he would like to submit is an oversimplification. He is therefore tempted to bring in reservations and qualifications to elaborate his point and to expatiate upon the methods he has used. There are two answers to his problem, I suggest, and the initiative in both cases lies with management. If the operational research analyst could know that the people he tries to help already understand the nature of his subject, he would not feel so diffident. It rests with management, when they introduce work of this kind, to see that the staff is fully informed. This surely means that the scientist must be given the opportunity to explain himself and his techniques ; something like a deliberate educational policy will have to be launched. But the operational research man needs educating, too. He has probably been brought up to believe that his job as a scientist is to determine the facts, and to leave management to make the decisions. He feels this responsibility keenly and thus becomes too scrupulous.

This brings me to what I consider a vital difference between the scientist who is engaged on pure research and the one who does operational research. In the second case, because his methods are management tools, the man himself partakes of the responsibility of management. If management wishes to decide between two courses of action, operational research should present the facts on which it can base that choice. But in determining what are the facts to put before the management, the analyst has to take a number of less important decisions himself. If he does not, he is asking the management to decide not only the major issue on which it asked his advice, but on a hierarchy of subsidiary decisions as well. This is where genuine scientific scruples lead to utter confusion. The operational research man wants to say : " if Mr. Jones was telling me the truth . . ." Management must teach him to accept responsibility for deciding whether Mr. Jones was telling him the truth ; the manager is not in a position to say.

Secondly, I think it is only human to recognise that the scientist who is trying to make the simple report that he knows is required, has his own personal and professional pride. When he has worked hard and wrestled long with an intractable problem, he does not want to be told that his " guess " has been noted along with those of others who he knows have scarcely considered the problem. In short, like everyone else, he does not want to be under-rated ; and this leads him almost unconsciously to give his reports that air of importance which the management will regard as incomprehensibility. If managers would understand this human shortcoming and treat it sympathetically, much of this difficulty would disappear. They can, after all, kill two birds with one stone ; for the suggestions offered in the last two paragraphs will answer this second, psychological, question as well.

Finally, there is a class of operational research which does not result so much in a report to management as in the installation of an operational solution—a method to be adopted in the works, or a system of control to be installed. Here again simplicity is the keynote. It is rightly demanded that procedures that have to be handled by workpeople or clerks should be within their capacity to operate. Thus, operational research should give the closest attention to translating its original (and justifiably) complex treatment into a workable form. To do this, it may be necessary to install permanent operational research controls at the centre to ensure the continued validity of the simplified translation which is being used in the works. A central control of this kind is often to be found, and should be regarded as the real solution to the paradox of complexity versus simplicity. In effect, this practice divides the problem of handling a difficult situation into two parts : the complexities are removed from the problem and handled at the centre, and large-scale applications can then safely be dealt with by more junior staff in the works in terms of simplicities.

The Question of Productivity.—The second of these comments concerns not operational research itself, but one of the applications discussed earlier in this paper. Mention was made of productivity measurement of an advanced kind, and the various uses to which such measurements have been put were described. Since operational research does not engage in a study of this kind without learning a great deal about the mechanisms involved, it would be remiss if I were not to offer some of the conclusions about the question of productivity to which I have come. It is widely claimed that our national difficulties are only to be overcome by higher productivity. This means that productivity is not at this moment as high as it could be ; that some of it is " missing." Where is it ?

There is a glib answer to this question, which says that " no one works hard these days." Therefore, it is argued, the missing productivity is up the sleeve of the operative. This is no more than a half-truth. If within the accepted structure of a man-machine process, all the labour factors in the operational research model are set at conditions of 100 per cent effort (that is, at a level of " sweated labour "), my experience is that an overall increase in productivity of perhaps 2 or 3 per cent is indicated by the model. There is great scope for increasing productivity, and yet within the system intense human effort cannot make much impression. We cannot be satisfied with this ; the

models must also be made to say where the missing productivity has gone. This they can do. Consider a large plant as an organic whole—which is what it ought to be. Its smooth flow of material, the fitting together of the separate parts of production, the need neither to overload the digestion of any machine nor to starve it, the purification of the blood-stream that supplies the vital services, and the health of the nerves that carry the communications of control ; all these organic requirements are the criteria of efficiency.

From our models we learn that for every few per cent of increased productivity that is obtainable by sheer labour effort, something between 20 and 50 per cent is available in terms of better " body tone," of truly organic behaviour. This could be achieved, according to our research, in terms of (and I am going through the physical analogies just drawn) smoother flow, better planning, better machine loading, better servicing and better communication and control. These aims are doubtless already objects of management everywhere ; but I am not speaking of a mere improvement in present conditions. To achieve real liveliness, or, should I say this time, life-like-ness, a step is required from our present concept of an " integrated works " to the concept of an " organic works." The features of a factory wherein this organic wholeness lies, which I have listed, need rethinking, not just improving, on a scale not yet imagined. This is not an argument from the inevitability of technical change ; it is an argument from the operational research model. Here alone we have the opportunity to understand the interactions of the parts within the organic whole.

Imagine processes A, B and C. Process B tends to be a bottleneck, although a work study investigation has revealed that there is plenty of spare B capacity. A large incentive bonus is therefore applied to process B. Production and wages rise, but there is still a bottleneck. And yet there is reason to think that labour effort is still well below standard. What has happened ? If we plot the probability distribution of real effort (say, the productivity index), we are likely to find statistical truncation ; that is, instead of the usual " tail " on the right, there is a sudden precipice. This means that unnatural limits are being set to effort in process B. Either the labour force has carried its bonus earnings to a point where they are as high as it thinks management will permit, or the flow from process A and into process C is too erratic or unplanned to permit a high rate of B productivity. This is what I meant by talking about " the accepted man-machine structure." Although labour is not working very hard, it is effectively prevented from working harder by either an economic or a manufacturing constraint. If operational research is asked to study the man-machine system A–B–C as an organic whole an answer may be found.

Finally, there is a point of great economic importance. Changes in the whole nature of the organic functions mentioned would presumably involve some capital expenditure. But this is not expenditure on a large scale ; the factory, to all appearances, would remain unchanged. By its " animation " we reach towards the full utilisation of existing resources. At a time when industry is preoccupied with large-scale expansion, this utilisation of existing resources sounds a dull theme. The phrase itself is colourless jargon. I will use a more ancient and more telling admonition. " Milk the cow that is at hand," said Theocritus, " why pursue the one that flies ? "

Integration with Management.—This point can be made briefly : it follows as a corollary of the last two sections of this discussion. Operational research is in fact operational ; its results should be built into management technique.

The operational research approach can be integrated with management functions, and can be made implicit in the system whereby the factory runs. Once methods of this kind have been installed, a manager should have the surety that when he looks at data, he is not being set a series of traps in which he will become ensnared unless all his experience and judgment are brought to bear with constant vigilance. He should be able to feel that operational research has ground a scientific outlook into the lenses of the glasses through which he views the operations under his control.

Faith, Hope and Probability

This review is now complete; it has ranged widely over the field for the industrial application of operational research. Many techniques have been introduced, and with them quite a large number of technical terms. I fully expect that these new ideas will spread themselves so widely, and with such impact, that informed people in industry will sooner or later want to recognise these terms in speech and in print.

I am asking much in presenting so long and difficult a paper ; the case must rest on a claim for the importance of this approach. British industry is without doubt a proud and worthy institution, but one perhaps seriously encumbered by its very Britishness. Some typical phrases resound in the ears of operational research workers. " It may work there, but this place is different " (but is it ?). " What about the human element ? " (what about it ?). " I am a simple sort of chap " (he never is). " There are too many variables " (abdication, this). And so on ; we fall back on the reputation for muddling through. As an operational research man, my affectionate description of this industrial scene is : faith, hope and probability.

And yet there is much which really worries us. Britain falls desperately behind Russia and America in the productivity race ; they have discovered that quality and quantity are not (as we so often suppose) mutually exclusive. Some strange blight has turned a war well won into a Phyrric victory ; we are outpaced by those we vanquished and laid low. An Englishman rather naturally turns for his harrowing example of this to ships. For all time (excepting only wartime in America) Britain has led the world's production. In 1956, while we launched less tonnage than in 1954 and 1955, Japan more than doubled her output and snatched the lead. Germany is now very close behind. Thus Great Britain forfeits her historic leadership and the proud title of the world's shipbuilder. We have heard the official explanations ; but where is the cry of anguish ?

It is this typical absence of alarm or even concern that prompts me to end on this note. Our problems are obviously great, and I should say unique in the world. We cannot afford to be mesmerised by soothing spokesmen, nor to be taken in by our own advertising. In invention and design we may still be among the leaders, and much of our plant is superb. But those who take too much pride in this are ignoring the international facts of trade. They are proponents of smugness. There is a new dimension of industrial management to be discovered : the cybernetic dimension, the dimension of liveliness. There are all the components of a body to hand ; they await techniques of assembly into an organic whole. Britain can lead in this effort too ; then her industrial economy can get up and run.

Now this is a diagnosis, and not a cure. It is not for operational research to resolve the country's predicament, and I am not selling a panacea. Management alone can do the job, management of all kinds : political management at ministerial level, administrative management in the civil service, line management in industry itself, functional management in engineering. But it is, I propose, significant that operational research has an approach to offer management of every kind, and a set of powerful tools which are uniformly applicable. This may help not only to solve the problems, but to supply the need for cohesion.

It is sometimes held that operational research men are simply people with critical intelligence and the time to think ; they are employed by managers too busy to stand back and think for themselves. Provided that no one ignores the special orientation, the mastery of analogy and probability, and the battery of special techniques which characterise operational research, this definition will do. But " time-to-thinkers " must come out of their brown studies to convey their thoughts. This I have tried to do in the course of this exposition, and my thought is of a great industrial emptiness : the absence of organic control. If some sense of this void has been conveyed, that is well. If some awareness of the new dimension in which such control could subsist has been communicated, that is better. And I cannot hope to convey the excitement that I personally feel as we move into this new dimension.

National Research Development Corporation

The report and statement of accounts for the year July 1, 1955, to June 30, 1956, of the National Research Development Corporation has recently been published. It will be recalled that one of the statutory functions of the Corporation, as provided in the Development of Inventions Act, 1948, is " to secure, where the public interest so requires, the development or exploitation of inventions resulting from public research, and of any other invention as to which it appears to the Corporation that it is not being developed or exploited or sufficiently developed or exploited." Previous reports have referred to the considerable support given to the development in this country of electronic computers, and as the result of this effort, says the report, the Corporation's contractors are now making and selling such machines on their own account, subject to licensing arrangements with the Corporation. Two new projects were embarked upon during the year ; the first, which will, according to current estimates, take three years to complete, is an attempt to by-pass the stage of development through which computers in the U.S.A. have evolved in the last three or four years, in order to pass direct to a transistorised all-core type computer. The second new project in this field, the report continues, is related to the use of an electronic computer for a specific business purpose, namely, for the inventory of engineering stores and the production control of complex equipment. Amongst the new development projects commenced during the year the report records the support the Corporation is giving for the development by Professor F. C. Williams, at Manchester University, of a form of variable-speed squirrel-cage induction motor.

Metallurgical Topics

Dynamic Yield Strength of Steels

IT is well known that metals may be subjected momentarily to stresses far exceeding their static yield strength without suffering plastic deformation. The actual measurement of the tensile yield strength at high rates of application of stress involves the use of fairly complicated equipment; and the development of suitable apparatus for testing tensile specimens at high rates of strain was the main object of a recently reported research by E. Siebel and G. Menges.[1]

For this purpose they made use of a heavy steel disc, rotating at high speed and provided with a firmly attached striking projection, on similar lines to the fly-wheels used by Guillery for notched-bar impact tests and by Luerssen and Greene for impact torsion tests. At any given moment the test specimen could be swung into the path of the projection. The striking

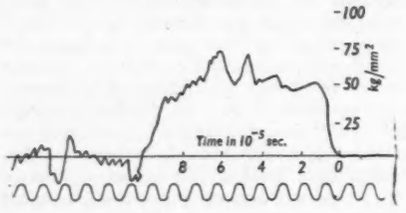


Fig. 1—Diagrammatic representation of photographic record of a high-speed test on steel C 15

velocity applied to a specimen of 30mm acting length, or less, could be varied from 5m to 100m per second. Stress was measured indirectly by means of the electrically recorded elastic extension of a dynamometer rod or "weigh bar," which was either an integral part of the specimen or into which the specimen was screwed. The possible error in stress measurement was estimated at ±8 per cent. The yield point was indicated by the first marked deviation in the rate of rise of stress. The dynamometer part had to exceed a certain minimum length in order that the record of the yield point and the first sign of plastic deformation should not be masked by disturbing reflections when high rates of strain were employed. These were most troublesome when a separate dynamometer bar was used. Fig. 1 is reproduced from a photographic record of a test in which the dynamometer was integral with the test piece. Here the strong reflections first set in after 3×10^{-6} second, after the first part of the deformation curve had been drawn.

With this apparatus, tests were made on three steels (Table I) to ascertain the effect of a rate of application of stress of 10^7 kg per square millimetre per second, and to determine the effect of temperature on these high-speed tests.

TABLE I—*Composition and Properties of the Normalised Steels*

(Siebel and Menges)

	St 37	C 15	C 60
Composition, per cent :			
Carbon	0·08	0·15	0·61
Silicon	0·18	0·25	0·25
Manganese	0·45	0·37	0·65
Sulphur	0·1	0·045	0·045
Phosphorus	0·1	0·045	0·045
Static Tests :			
Tensile strength, tons per square inch	30·0	28·6	45·1
Elongation, per cent ...	35	36	26
Upper yield point, tons per square inch (Y_s)	22·6	19·4	26·0
Reduction of area, percent	56	42	44
Dynamic Tests at 10^7 kg per square millimetre per sec.:			
Upper yield point, tons per square inch (Y_d)... ...	39·4	34·9	52·0
Reduction of area, per cent	53	40	50
Ratio : Y_d/Y_s	1·74	1·80	2·00

It was found that at a rate of increase of stress of 10^7 kg per square millimetre per second the upper yield point was about doubled in comparison with its value in static tests, whereas the effect of rate of strain on the reduction of area was much smaller. In St 37 in the strain-aged state and in C 60 in the normalised condition a slight increase in reduction of area accompanied the increased rate of application of stress. The effect of a notch in the test piece was to increase the upper yield by about the same amount at all rates of strain, but to produce a much more rapid fall in reduction of area (Fig. 2).

The influence of the testing temperature was studied under conditions in which the rate of increase of stress was 10^7 kg per square millimetre per second. The upper yield point increased with decreasing temperature of testing up to the attainment of the cleavage strength. This was reached for St 37 at –5 deg. Cent., for C 15 at –45 deg. Cent., and for C 60 at –50 deg. Cent. Up to a similar temperature in each case, the reduction of area remained almost independent af the temperature of testing, but then fell quickly to a zero value. Results are shown in Fig. 3. These data may be regarded as further confirmation that brittle fracture originates through raising the upper yield point to the cleavage strength. The microscopical study of polished specimens showed pronounced twinning in test pieces which broke without deformation, especially in the neighbourhood of the fracture. This development of twin crystals and Neumann bands has been noted by all who have investigated steels which have fractured under conditions of high speed and low temperature

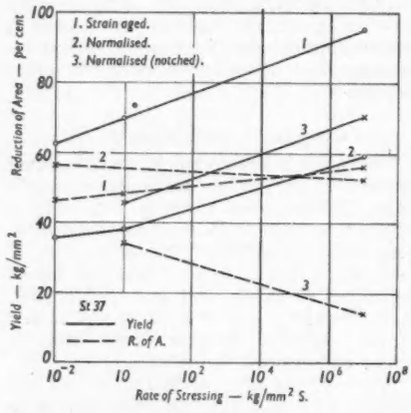


Fig. 2—Influence of rate of rise of stress on the upper yield point and reduction of area of St 37 as strain-aged and as normalised (smooth and notched specimens)

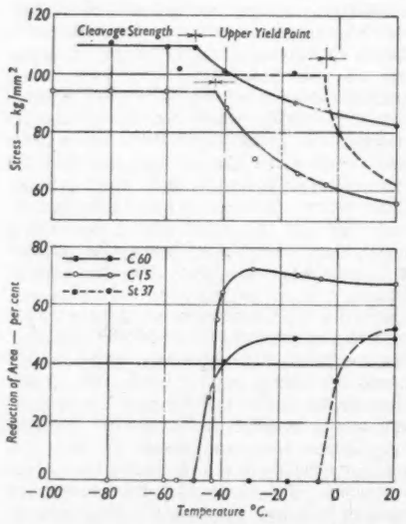


Fig. 3—Upper yield point, cleavage strength and reduction of area of normalised steels in relation to temperature of test (rate of increase of stress, 10^7 kg per square millimetre per second)

The experimental arrangements appeared to be well suited for ascertaining the transition temperature from tough to brittle fracture of smooth tensile test pieces stressed at different rates. For such a purpose electrical measurements of stress could be dispensed with, as the reduction of area alone is a suitable characteristic for ascertaining the transition temperature.

The effect of rate of strain on the tensile yield strength was in general agreement with that found by Sir G. I. Taylor and his collaborators[2] on the compression yield of carbon steels of similar carbon content, and also with those of A. F. C. Brown and N. D. G. Vincent[3] and of J. Gibson[4] on the effect of speed of testing on the tensile yield point. The ratio of dynamic to static yield did not, however, fall with increasing static yield point as appears to be the general tendency, though one subject to a high degree of scatter which might mask the effect in steels with static yield points as close together as those of the three steels investigated.

In dynamic tests there is insufficient time for the strain corresponding to a given stress to attain its full value. As pointed out by Dr. Gibson,[4] repeated loading would give yield points tending towards the static value although, owing to accumulated strain, there may be an increase in the lower yield stress, related to the overall amount of deformation undergone. The existence of a dynamic upper yield stress may give additional strength to a material subjected to dynamic loading, but this should not be relied upon in dynamic design any more than the static upper yield stress is used in static design since these effects occur only when sufficient care is taken to provide axial loading.[4]

[1] *Archiv für das Eisenhüttenwesen*, January 1957, page 31.
[2] *Proc. Royal Society*, 1948, A. Vol. 194, page 289.
[3] *Proc. I.Mech.E.*, 1941, Vol. 145, page 126.
[4] *Proc. (B) I.Mech.E.*, 1952-53, page 536.

Embrittlement of Nickel-Chromium Steel

THE nature of the embrittlement associated with the tempering of nickel-chromium steel has been discussed in two recent papers. It has been shown that there are two temperature ranges in which brittleness is developed. The lower range extends downwards from about 600 deg. Cent. with most rapid embrittlement occurring at 550 deg. to 490 deg. Cent. and continuing to lower temperatures where the embrittlement becomes very slow. In the upper range, extending from about 690 deg. Cent. downwards, embrittlement is most rapid at 675 deg. Cent., becoming very slow as the temperature is lowered. From the shape of the curves representing the transition temperature of tough to brittle fracture in relation to time and temperature of reheating, L. D. Jaffe and D. C. Buffum now refer to the embrittling effects of these two separate ranges of temperature as "double-nose temper brittleness," upper nose embrittlement being most rapid at 675 deg. Cent. and lower nose embrittlement most rapid at about 500 deg. Cent.

In a paper entitled "Upper Nose Temper Embrittlement of Ni-Cr Steel," Jaffe and Buffum* have compared and contrasted the characteristic features of each type of embrittlement. Microscopical examination showed that embrittlement in the lower range was accompanied by rapid grain-boundary attack by ethereal picric acid and fracture along austenite grain boundaries. Embrittlement in the upper range was accompanied by slow attack by ethereal picric acid and fracture mostly along ferrite grain boundaries. Grain growth was not associated with either treatment. In both, carbide particles visible under the microscope remained spheroidal and showed little tendency to concentrate at grain boundaries, though they increased in size during treatments in the upper temperature range. Embrittlement during slow cooling from 675 deg. Cent. (the "Krupp-Krankheit" to describe which the term "temper-brittleness" was first

* *Journal of Metals*, January, 1957, page 8.

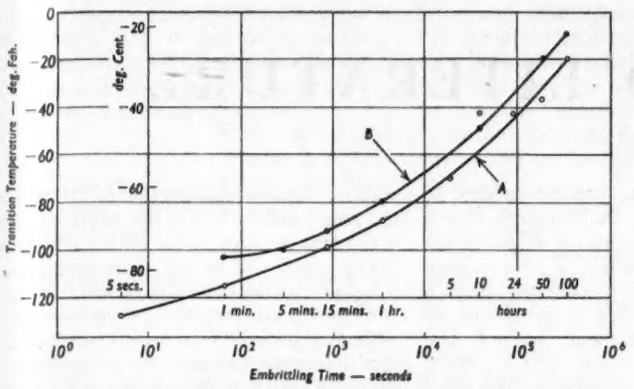


Fig. 1—Comparison of embrittlement in specimens directly heated at 675 deg. Cent. (Curve *A*) with that of specimens reheated at 675 deg. after prior embrittlement at 500 deg. Cent. for fifty hours (Curve *B*).* (Bhat and Libsch)

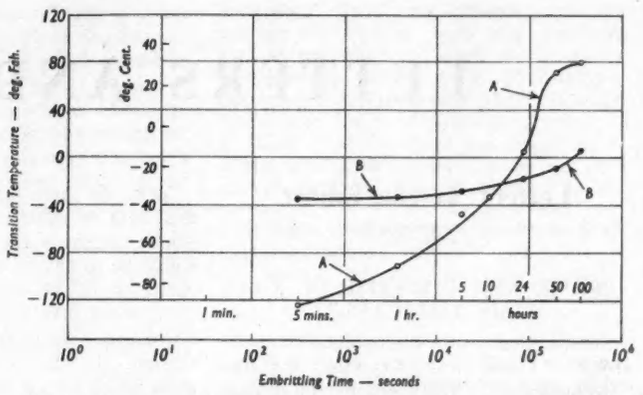


Fig. 2—Comparison of embrittlement of specimens directly embrittled at 500 deg. Cent. (Curve *A*) with that of specimens reheated at 500 deg. after prior embrittlement at 675 deg. Cent. for fifty hours (Curve *B*).* (Bhat and Libsch)

introduced), is primarily associated with the lower range and takes place below 600 deg. Cent. Jaffe and Buffum's comments on the causes of embrittlement are of rather a negative character. They state that " the two commonly accepted explanations of upper nose embrittlement—ferrite grain growth and carbide particle growth—seem difficult to reconcile with the experimental observations. Of the two commonly accepted explanations of lower nose embrittlement—segregation of dissolved atoms to grain boundaries and precipitation of an unidentified phase at grain boundaries—the first seems impossible to reconcile with the experimental observations."

In a paper by G. Bhat and J. F. Libsch,† data are presented to show that embrittlement in a nickel-chromium steel proceeds by one mechanism at 500 deg. Cent. and by a different mechanism at 675 deg. Cent. The embrittlement occurring at 500 deg. Cent. may be removed completely by reheating to higher temperatures for a very short time, and has no influence on further embrittlement at 675 deg. Cent. The embrittlement occurring at 675 deg. Cent. appeared to be related to a permanent structural change which had a significant retarding influence upon the subsequent development of embrittlement at 500 deg. Cent.

In Fig. 1 the transition temperatures of specimens directly embrittled at 675 deg. Cent. are compared with those of specimens which were heated at 675 deg. Cent. after an embrittling treatment at 500 deg. Cent. for fifty hours. The hardness values of the specimens represented by the two curves were similar at any given time, but fell from R_c 32 to R_c 11 (305 to 190 Vickers) as the time at 675 deg. was prolonged. It is evident that the prior embrittlement at 500 deg. Cent. had practically no influence on the development of embrittlement at 675 deg. Cent. It was, in fact, found in another connection that when specimens embrittled at 500 deg. Cent., after preliminary induction tempering (675 deg. Cent. for five seconds), were reheated to 675 deg. Cent. for five seconds, the transition temperature returned to a value characteristic of the unembrittled specimens.

In Fig. 2, transition temperatures of specimens directly embrittled at 500 deg. Cent. are compared with those of specimens reheated at 500 deg. Cent. after prior embrittlement at 675 deg. Cent. for fifty hours. Specimens directly embrittled at 500 deg. Cent. had a hardness of R_c 32 to 34 (305 to 327 Vickers), whilst those that had received the preliminary treatment at 675 deg. Cent. had a hardness of R_c 11 to 15 (190 to 202 Vickers). The preliminary heat-treatment at 675 deg. Cent. had a marked influence on the subsequent development of embrittlement at 500 deg. Cent.

In Bhat and Libsch's opinion embrittlement at 500 deg. Cent. and its removal by reheating for a very short time at 675 deg. is consistent with either (*a*) nucleation and growth of a precipitate, and its solution with increased solubility at higher temperature, or (*b*) segregation of solute elements to prior austenite grain boundaries, and redistribution of the solute elements as numerous well-defined ferrite grain boundaries develop with prolonged tempering at higher temperatures. Embrittlement at 675 deg. Cent. appears to involve a permanent structural change which affects subsequent behaviour in a manner which is consistent with the development of well-defined ferrite grains, their growth with increasing time, and their influence upon distribution of a precipitate or segregate on subsequent reheating at 500 deg. Cent.

There is evidently a wide divergence in the views expressed in the two papers. It seems, however, quite definite that changes undergone at 675 deg. Cent. and at 500 deg. Cent. are essentially different in their origin and their effect, especially when account is taken of their effect on physical and mechanical properties (e.g. hardness, elastic limit, &c.), other than brittleness and transition temperature.

The understanding of temper brittleness in its original sense of a change taking place at temperatures well below the critical range and below the maximum normal tempering temperature of the steel does not seem to be advanced by the conception of " double nose temper brittleness," linking it up as part of the same process as occurs in prolonged tempering in close proximity to the critical temperature.

Control of Strain-Ageing

THE effect of strain-ageing—the change in the properties of cold-worked metals and alloys which occurs during storage—is detrimental to the behaviour of deep drawing steels. There is an increase in yield strength and loss of ductility which may lead to buckling and tearing during drawing, and at the same time the return of the yield point (suppressed by cold working) results in the formation of Luders' lines and stretcher strains during pressing operations. The practical control of the strain-ageing of α-iron or very low carbon steels has been investigated by E. R. Morgan and J. C. Shyne.* Their object was to examine the relative efficiencies of the various treatments which have been suggested for the control of the amount of carbon and of nitrogen—in solid solution in α-iron. It is often impossible to carry out drawing or pressing before ageing sets in, and with large steel components retardation of ageing by cold storage is impracticable. Moreover, the effect of ageing after the drawing operation is frequently objectionable especially when accompanied by embrittlement. Ferrite remains to a slight degree supersaturated with carbon and rather more so with nitrogen even after slow cooling (box annealing). Carbon in solution can be effectively reduced by quenching from 700 deg. Cent. and subsequently ageing at about 200 deg. Cent. The removal of carbon from solution is, however, of secondary importance compared with the problem of the control of the amount of dissolved nitrogen.

Tensile testing was chosen as the best way to follow the progress of strain-ageing. The procedure was to pre-strain the specimens 7½ per cent. The mechanical properties measured after ageing at room temperatures, 60 deg. Cent. and 100 deg. Cent. for various times were the ageing index (Fig. 1), ultimate tensile strength and elongation per cent on 1in (diameter of test piece 0·25in). Three possible types of basis metal were examined, the variables being carbon and oxygen content. The results showed that the carbon-reduced, vacuum-melted iron (carbon 0·06, oxygen 0·0014, nitrogen 0·0001 per cent) showed least ageing, as measured in terms of ageing index, increase in tensile strength and decrease in elongation. By water quenching from 707 deg. Cent. and ageing at 205 deg. Cent. for 160 hours the effect of subsequent strain-ageing was almost eliminated. With the addition of 0·005 per cent of nitrogen the steel showed

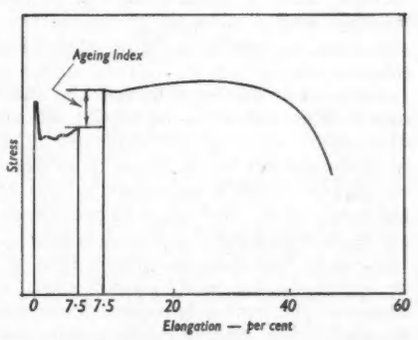


Fig. 1—Typical tensile test curve for a strain-aged steel

marked strain-ageing which was not suppressed by a preliminary quenching and ageing. To this basis material (carbon 0·06, nitrogen 0·005 per cent) additions of titanium, aluminium, vanadium or boron were made. Each of these eliminated nitrogen strain-ageing, but the effectiveness of aluminium and boron could only be seen from the strain-ageing of samples which had previously been quenched and aged in order to eliminate carbon strain-ageing. The strong carbide-forming and nitride-forming elements, titanium and vanadium, were effective in suppressing both types of strain-ageing. Titanium and aluminium cannot, however, be regarded as economically satisfactory as they are strong deoxidisers and produce killed steel characterised by low ingot-to-slab yields. On the other hand, vanadium (the use of which was proposed by Epstein† and later investigated by W. R. D. Jones and G. Coombes‡) and boron are not strong deoxidisers and effectively reduced the amount of nitrogen in solution in a rimming steel. Unfortunately addition of the necessary amount of vanadium is expensive, and for these reasons boron which was found by Morgan and Shyne to be effective in specimens with high and low oxygen content and moreover is inexpensive, is recommended by them as being a most promising addition to prevent nitrogen strain-ageing.

* Composition of steel : carbon 0·39, nickel 1·26, chromium 0·77 per cent. Preliminary heat-treatment : oil-hardened from 900 deg. Cent. and tempered by induction heating at 675 deg. Cent. for five seconds.

† *Journal of Metals*, January, 1957, page 20.

* *Journal of Metals*, January 1957, page 65.

† *Journal of Metals*, June 1950, page 830.

‡ *Journal I.&S.I.*, 1953, Vol. 174, page 9.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents.)

PRAISE AND DISPRAISE OF THE " MECHANICALS "

SIR,—I read with disappointment your article " Praise and Dispraise for the ' Mechanicals.' " The decisions you discuss were doubtless the fruit of some deliberation, and they may be assumed, as matters of passing interest, to represent the policies of at least part of the membership. But you, Sir, attending multitudinous meetings of this and other bodies, are in a better position than any one else to draw attention to the conduct of ordinary meetings and discussions, which, in my more limited experience, is characterised by a lack of punctuality, the wasting of a large proportion of time on unnecessary formalities, and the extraordinary disrespect of the members for the instructions of the chairman. I doubt if any of the applications for membership were signed with a cross ; there is no need to read aloud to the members the biography of the speaker, nor defence for his reading extracts from a printed lecture. Those members who consider the paper worthless stay away, so there is no call to praise it in the discussion.

Further, I would dispute the policy whereby important lectures are to-day passing without discussion ; this happens alarmingly often when the speaker is one whose views might be accepted without scepticism by part of the membership. How many mere engineers are there who have mastered a subject so thoroughly that there is nothing that can be added by an entire learned society ? Moreover, the worth of the paper is diminished sharply if there is no discussion, since then every individual who wishes to draw upon it must examine it in great detail to assure himself that it meets his requirements ; as an example of a paper that I shall not accept in the absence of confirmation by participants in a discussion, I cite Lord Douglas's recent lecture to the Institute of Transport—the entire conclusion, that turbo-prop aircraft are more economic than turbo-jet, appears to me to hang on whether the " Comet " is or is not representative in exceeding its estimated engineering costs by 160 per cent.

Another practice that is at best dubious is holding discussions " off the record." At such meetings the standard of the contributions is often worse than puerile. I recall full well a recent discussion whose leader said nothing that an engineer could not have worked out for himself on general principles until, one hour and a quarter after the meeting opened, he revealed one item of his experience that could have occupied a meeting by itself—but he had no evidence or explanation to support this discovery. During this meeting he was continually questioned ; he did not answer one question, except to say that his costs were divided between labour, 85 per cent, and fuel, 17 per cent !

You, Sir- may have become resigned to this state of affairs. But I submit that a simple approach to a major improvement would be to have a permanent, professional chairman in the major societies. Such a man would take a pride in conducting an interesting, significant and relevant discussion. In the course of years he would learn which of the members could be relied on to " see that mind is engaged before putting mouth in gear," and which take savage liberties with the patience of the members. And, not having to stand for election, he would ensure that members, if asked to give their names, did so. Which leads me to one particularly attractive feature of this proposal, that for the posts filled by election it would be possible to appoint men honoured as engineers, regardless of their ability to conduct a meeting.

" HINCHCLIFFE "

London,
March 20, 1957

TERMINOLOGY IN GEARING

SIR,—In a recent article by Dr. Tuplin (" Let's Forget the Cycloid Tooth," December 14, 1956) it has been proposed to change from the term " pitch circles " and instead adopt " meshing circles." The writer wishes to present reasons why the old term is more in accord with practical considerations and also more logical. The discussion will be limited to the cross sections of gear teeth in a plane perpendicular to the parallel axes of two mating spur gears. It is obvious that gears that are to run together must have teeth of the same size. The numbers of teeth and their size determine the diameters of the gears, and the dimensions that establish tooth size are circular pitch and circular tooth thickness.

Pitch is a term long used by mechanical workers and others, as in the pitch of screw threads, the pitch of saw teeth, the pitch of a row of rivets. It generally means the distance between the elements of a series of similar equally spaced things or points. In a gear the circular pitch of the teeth is constant around any circle concentric with the gear, but it varies with the diameter of the circle. From the beginning, the pitch circles in a pair of gears have been those touching each other and on both of which the circular pitch has the same value. What is perhaps the first rule in gearing is that the diameter of a pitch circle can be known from the number of teeth and the circular pitch.

In imagination pitch circles roll together without slip, and in considering and understanding the kinematic relations of the contacting tooth profiles the idea of " rolling circles " is necessary, but it is not often needed in the gear cutting shop. Pitch circles are thought of in connection with tooth size (circular pitch), numbers of teeth, tooth design, and gear cutting tools. The idea of rolling circles is needed when tooth contact and the formation of tooth profiles are being analysed. In a pair of mating gears the centre distance equals the sum of the radii of the pitch circles ; and if the centre distance is changed the radii of the pitch circles must change also, and in the same proportion. The fact that the same pair of involute gears will operate satisfactorily and correctly after a small change of centre distance indicates that in any involute gear there may be pitch circles of differing diameters and on which the circular pitch changes with the diameter. And it has come to be said that " a gear has no pitch circle until it is put into mesh with another gear . . ." Such a statement is not in itself enlightening or instructive because it contradicts common practice in gear design and gear manufacture. Every gear has a pitch circle and may have several.

The specifications and drawing of a gear necessarily include information in regard to circular pitch (or alternatively diametral pitch), in order that the proper cutter or hob can be obtained and used to produce the gear. A gear generating hob marked " 10 diametral pitch," for instance, is intended for and capable of cutting teeth of that pitch. A gear generated by that hob is commonly known as a 10-diametral-pitch gear unless there is a definite reason for doing otherwise. And in the gear there is one pitch circle and only one on which the circular pitch corresponds to the standard " 10-DP " marked on the hob. The diameter of that circle can be exactly determined and is unambiguous. It is known as the " standard pitch diameter " in the gear. This is one of the most common ideas in both design and manufacture, but it appears to have been intentionally avoided in the British Standard Glossary of terms in gearing.

Because in an involute gear there can be different pitch circles under different conditions there must be different designations for them, such as standard pitch circle (standard according to the generating tool) ; pitch circle of generation; pitch circle of operation (running pitch circle) ; and testing pitch circle (with a master gear), &c.

The proposed term " meshing circles " can certainly be questioned. In the first place, it may be properly said that gear teeth " mesh with " each other ; but it does not seem satisfactory to say that " circles mesh," because " mesh " commonly refers to a network or interlaced structure, and the word can hardly apply to a pair of tangent circles. Even if the term " meshing circles " were adopted it would continue to be necessary to use the additional qualifying designations like standard, operating, non-standard, enlarged, special, contacted, generating, and testing. It will therefore seem to many that the reasons presented up to now do not justify the proposal to discard the long-standing term " pitch circle."

It is remarked finally that the term " reference circle " appears in the British Standard Glossary for what has been called here the " standard pitch circle." It is there related to a reference cylinder, which in turn is defined by connecting it to pressure angle.

It is surprising that none of the definitions in the Glossary indicate that the diameter of either the cylinder or the circle can be determined from the circular pitch and cannot be determined from the pressure angle.

ALLAN H. CANDEE
Fellow A.S.M.E.,
Hon. Life Member A.G.M.A.
Rochester 10, New York, U.S.A.,
March 3, 1957.

RAILWAY ELECTRIFICATION

SIR,—I note with interest from the pages of the current issue of THE ENGINEER that the Transport Commission are making arrangements to spend any number of millions of pounds on the electrification of surface railways.

But what, in spite of the most earnest endeavours, I have never found is any scrap of evidence that electrification is likely to be financially profitable.

Perhaps some of your readers could furnish facts and figures.

MONKSWELL
The Athenæum, Pall Mall, S.W.1,
March 16, 1957

[The economic justification for main line electrification depends upon a reduction in working expenses to balance the additional fixed charges incurred. According to the Weir Report, based on 1929 conditions, this balance should be attained when the traffic density reached 2,300,000 trailing ton-miles per annum per mile of single track running line ; at higher traffic densities the advantage would lie with electrification. In the 1951 report, " Electrification of Railways," published by the British Transport Commission, the critical figure for traffic density based on up-to-date costs was amended to between 3,000,000 and 4,000,000 trailing ton-miles per annum per mile.—ED. THE E.]

THE " JAGUAR " FIRE

SIR,—I was interested to read the letter in your issue dated March 15 from Mr. Caryl Thain, managing director of Robertson Thain, Ltd., regarding the Jaguar factory fire.

While agreeing with much of what Mr. Thain says about roof structures generally, I would suggest that his conclusions regarding the Jaguar fire, in so far as they lay emphasis on the lining of the roof with fibre insulating board rather than on the inflammable nature of the bituminous roofing itself, are incorrect. I myself accompanied the chairman of my technical committee on a visit to the Jaguar factory within a few days of the fire, and through the good offices of all concerned, including the management of the factory and the chief officers of the Coventry Fire Service, was able to obtain first-hand information regarding the probable sequence of events.

It was abundantly clear that the prime factor contributing to the rapid spread of the fire was the high bitumen content in the roof covering and flashings. It was apparent that this had melted and run ahead of the progress of the fire and naturally involved the fibre board lining as well as scattering over the whole factory area. This view is confirmed by the Technical Information Sheet issued by the Fire Protection Association in connection with the Jaguar fire. The title of this sheet is " Spread of Fire by Bituminous Roof Coverings," and in it the Fire Offices' Committee quote the parallel example of the largest recorded industrial fire which has ever taken place, the fire at the General Motors factory at Michigan, where the bituminous roofing became ignited, melted and the fire spread over practically the entire plant. In that case there was no fibre insulating board lining, a fact which speaks for itself.

Fibre insulating board is one of the most widely used and efficient insulating materials for the lining of buildings, but like any other material it should be used properly. When applied in existing buildings it naturally has to be added underneath the roof structure, and it is advisable to break up air spaces by fire stops and similarly not to leave open ends. Where the fire risk is high, as when fibre insulating board is used to line a roof with a high bitumen content, treatments are readily available which give a Class 1 spread of flame rating to fibre insulating board.

The necessity for proper structural precautions against fire, including fire breaks in large factory spaces, and for care in the storage and handling of inflammable contents of buildings, is applicable whenever materials are incorporated in linings or roof construction.

L. R. CHAMBERS
Director-General,
Fibre Building Board Development Organisation, Ltd.,
London, S.W.7,
March 25, 1957.

Literature

Steam Locomotive. By O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E., M.I.Loco.E., George Allen and Unwin, Ltd., Ruskin House, 40, Museum Street, London, W.C.1. Price 25s.

THIS new book by an old author, not so much in years but rather as a writer, offers a historical review of the doings of the many notable figures associated with the railways of Britain and, in particular, the locomotives for which they have been responsible. It is a story well told, which includes in its make-up many interesting references to the well-known locomotive engineers of the past ; the engines they built are described to a greater or lesser extent, while at the same time the author deals with what are termed the economic and political aspects which have played an important part in past policies and in bringing about many changing circumstances in railway life. Within the compass of ten chapters extending over 206 pages, a story is unfolded, extending from the opening of the Stockton and Darlington line in 1825 and the episode of the Rainhill trials in 1829, up to 1945. Obviously, no more than an outline could be accomplished, but it makes a readable story, spiced here and there with gossip which gives it a flavour of its own. Each of the chapters is given a specific title, though it is not always easy to relate it with the contents. A rather notable feature of this book is seen in the fact that throughout it refers almost without exception to locomotives for passenger services ; in fact, of the many illustrations all save three are of passenger engines.

Generally, the information given seems reliable, but perhaps two slight slips may be mentioned; both, strange to say, refer to the old Furness line. For instance, the picture facing page 65, described as " A Bury 0–4–0 Furness Railway " is actually one of the Fairbairns. This error is, however, excusable, because the Furness Bury and Fairbairn locomotives were very much alike. Again, when making mention of W. F. Pettigrew, Locomotive Superintendent of this line and later styled Chief Mechanical Engineer, it is stated that Pettigrew was Engineer in Chief, responsible for all engineering, Civil and Mechanical. This is definitely a slip on the part of the author, who has overlooked D. L. Rutherford, who was Chief Engineer during Pettigrew's later years on the railway and who eventually succeeded him by taking up dual duties as Chief Engineer and Locomotive Engineer. The author must surely remember the Rutherford 4–6–4 tank engines of 1920, as shown by one of the illustrations between pages 192 and 193. With the grouping of the railways in 1923, the Furness line, like so many others, lost its identity, and the aches and pains then experienced foreshadowed those to come with much greater intensity in 1948.

Taking this book for all in all, it may safely be commended as a chatty account of many aspects of locomotive development over the years, interspersed with numerous well-chosen illustrations of engines with, in certain instances, portraits of their distinguished designers. It is the result of a profound study of both ancient and more modern history and is, moreover, nicely presented by the publishers.

The Use and Welding of Aluminium in Shipbuilding. Institute of Welding, 29, Park Crescent, London, W.1. Price 32s. 6d. and 26s. 6d. to members of the sponsoring organisations.

THIS volume contains the proceedings of a Symposium, organised by the Institute of Welding, the Institution of Naval Architects the British Shipbuilding Research Association and the Aluminium Development Association, at which twenty-one papers were read and discussed. The papers represent an up-to-date survey of the experience of many of the leading shipbuilding countries in Europe, and cover most aspects of the welded fabrication and use of light alloys in shipbuilding. There are four sections in the book, into which the papers and discussion are grouped under the following titles : welding processes and techniques ; materials and design ; applications ; and applications and economic factors.

Books Received

High Speed Diesel Engines. By Arthur W. Judge. Fifth edition. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 65s.

Technical Aspects of Sound. Vol. II. By E. G. Richardson. Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 70s.

Modern Wiring Practice. Third edition. By W. E. Steward. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 25s.

The Railway Station : An Architectural History. By Carroll L. V. Meeks. The Architectural Press, 9-13, Queen Anne's Gate, London, S.W.1. Price 60s.

Amplifiers : Design and Construction. By F. J. Camm. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 17s. 6d.

The Nature of Management. Second edition. By H. R. Light. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 12s. 6d.

Digital Calculating Machines and Their Application to Scientific and Engineering Work. By G. A. Montgomerie. Blackie and Sons, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 30s.

Jet Engine Manual. Second edition. By E. Mangham and A. Peace. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 10s. 6d.

Diesel-Electric Paddle Tugs for the Navy

By G. W. TRIPP, O.B.E., F.C.G.I., M.I.C.E.

WHEN diesel and diesel-electric drive became increasingly adopted for ship propulsion, it appeared as if the paddle boat was doomed to extinction. Then came the interesting Clyde passenger vessel, "Talisman," with diesel-electric drive, an electric motor being mounted direct on the paddle-wheel shaft. This vessel has given good service before, during and after the war. Another interesting paddle boat with diesel engines is the Isle of Wight car ferry, "Farringford," whose independent paddle wheels are chain driven. Now a further lease of life for the paddle boat has been given by the Admiralty decision to replace some of its older paddle tugs by seven diesel-electric paddle boats. It has been found that the paddle tug is specially useful for handling aircraft carriers and other large naval vessels, for which purpose a fleet of ten steam paddle tugs has been kept in commission, taking their place alongside their screw-propelled sisters. Admittedly, these vessels are becoming veterans, but thanks to good care and maintenance they have continued to give efficient service. It may be of interest to name them, giving in brackets their age in years. Stationed at Portsmouth are ; "Sprite" (40), "Swarthy" (42), "Grappler" (46), "Volatile" (58) : at Devonport ; "Pert" (39), "Camel" (40), "Industrious" (52) : at Sheerness ; "Cracker" (56) : at Rosyth ; "Firm" (44) : and at Malta ; "Robust" (48). "Volatile" (Fig. 1), the first to be retired, was built in Glasgow in 1899 and had a displacement of 700 tons ; driven by compound diagonal oscillating engines, with a boiler pressure of 75 lb per square inch, she attained a speed of 11½ knots. She had a crew of sixteen. During the first world war she was transferred to Rosyth to help bring into harbour warships damaged in the Battle of Jutland. Incidentally, when the Cunard Liner "Queen Elizabeth" went aground off Calshot in 1948, "Volatile" assisted in refloating her.

When the Admiralty decided that the time had come to replace the oldest of these tugs, the bold decision was made to order seven paddle tugs, this time to be equipped with diesel-electric drive. An order for the first two, "Director" and, "Dexterous," was placed with Yarrow and Co., Ltd., of Scotstoun, followed by another order for two more with Wm. Simons and Co., Ltd., of Renfrew. As will be seen from the illustrations (Figs. 2 and 3), they are of somewhat unusual appearance, with two squat funnels placed abreast (in which, as well as the exhaust, various tanks are housed) and raked stem, while to enable them to operate under the overhanging sides of aircraft carriers, they are fitted with hinged masts. Although primarily intended for harbour service, they are constructed under special survey, to Lloyd's Class "100A1" "for towing and salvage services," including assignment of load line, so as to enable them to proceed to sea. Accommodation, life-saving equipment, lights and signals are to the requirements of the Ministry of Transport and Civil Aviation.

The principal dimensions of these vessels are : length, overall, 157ft, between perpendiculars, 145ft; breadth, moulded, 30ft, overall, 60ft ; depth, moulded, 15ft ; draught, load, 10ft ; displacement, load, 710 tons ; tonnage, 473 gross. The estimated bollard pull is 15 tons.

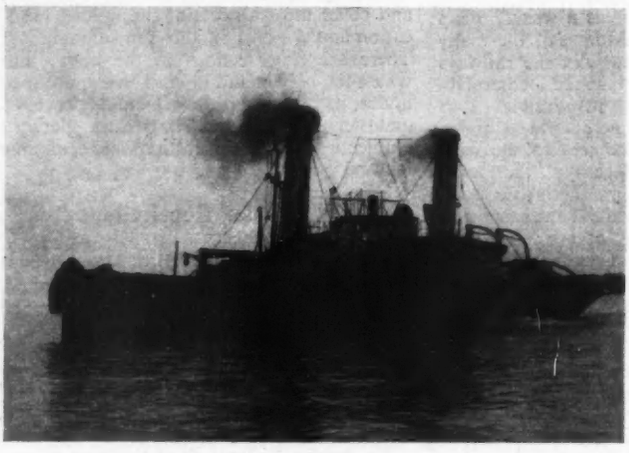


Fig. 1—H.M. tug "Volatile," (1899)

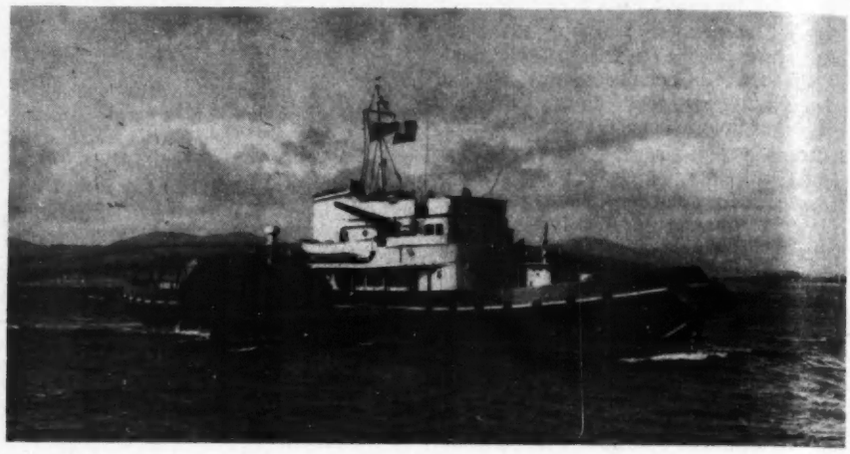


Fig. 2—H.M. tug "Director"

Fig. 3—Bow view of H.M. tug "Director"

Provision is made for a company of twenty-one, there being six officers and fifteen crew. The captain's cabin is on the bridge deck beside the chart, wireless telegraphy, and radar room, and adjacent to the wheelhouse, which is constructed of aluminium alloy in the vicinity of the compass. Kent clear-view screens are fitted. A deckhouse on the upper deck has a cabin for the chief engineer, a saloon, galley, bath room, and also a drying room, lamp room, and fan space. On the lower deck is accommodation, including two double-berth cabins for officers, two cabins, with seven and eight berths respectively, for crew, and also a crew's mess. At the after end of this deck are store and hawser rooms, and the steering gear compartment, while the bos'n's store is in the hold with access from the upper deck. In order to ensure good manœuvring and steering, a rudder of large area has been provided, actuated by electric hydraulic steering gear with telemotor control from the wheelhouse, arrangement also being made for emergency hand-steering.

The main machinery (Fig. 4) consists of four diesel engines of Paxman type 12YHAX, driving 339kW, 305V generators at 1600 r.p.m., which with the propulsion motors, exciters, control gear and ancillary equipment, are of British Thomson-Houston manufacture. The propulsion motors transmit 800 h.p. at 212 r.p.m. and 600V, and drive the paddle wheels through a Renold chain drive with an 8 to 1 reduction ratio. Each motor can be controlled from either the bridge or engine-room. The paddle wheels are feathering with star centre arranged inboard and on the paddle block. They have a diameter of 17ft. For normal harbour service the paddle shafts will be independently operated, but a dog clutch is provided for coupling them together quickly in the event of the vessel proceeding to sea. A flexible coupling is fitted between each motor and its pinion shaft and a semi-flexible coupling in each paddle shaft. The pinion and wheel shafts are supported in roller bearings. Arrangements have been made to facilitate unshipping of all the machinery and auxiliaries so that they can readily be removed for overhaul ashore and be replaced by similar units from a stock of spares. Both the Paxman main engines and Foden auxiliary diesels are identical with those fitted in the Admiralty screw tugs. To facilitate quick removal of parts, the layout of ventilation and engine exhaust trunks has been arranged to reduce to a minimum the amount of dismantling necessary and has

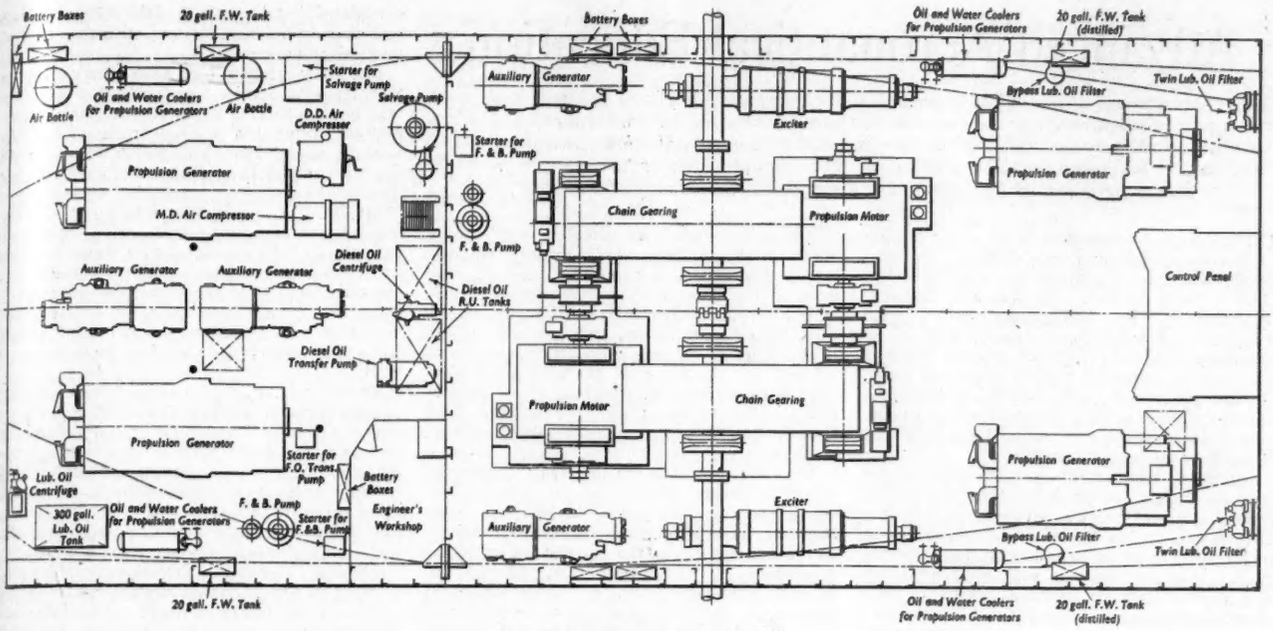


Fig. 4—Arrangement of machinery

resulted in the use of twin funnels amidships.

Electricity for general purposes is provided by four Foden 60kW, 220V generators. Among the principal auxiliaries may be mentioned two 30-ton-hour self-priming vertical centrifugal motor-driven bilge and fire pumps ; one 150-ton-hour self-priming vertical centrifugal motor-driven fire and salvage pump, so arranged as to discharge foam compound to two Pyrene distributing heads and to two monitors as well as the usual water for fire and wash-deck services ; one 800-gallon-hour horizontal positive displacement, motor-driven diesel oil transfer pump; all the foregoing pumps being of Hamworthy manufacture. Reavell and Co., Ltd., has supplied a motor-driven 16 cubic foot air compressor with heater, and one diesel engine (Enfield HD2, Mark II) driven 16 cubic foot air compressor. Alfa-Laval Co., Ltd., has supplied a 25-gallon lubricating oil purifier, and a 100-gallon diesel oil purifier. The rudder is operated by electric hydraulic steering gear, by MacTaggart Scott and Co., Ltd., with telemotor control from the wheelhouse, and also arranged for emergency hand steering. The deck machinery includes a 16 h.p. electric anchor windlass for handling 1¼in diameter cable for the 12-cwt anchors, and fitted with warping drum at each side ; there is also a 30 h.p., 24in diameter, electric after-warping capstan. The two towing hooks are of "Monarch" patent shock-absorbing type, each having been tested to 50 tons, these being fitted at the after end of the bridge deck, with guide rails and stops.

The fire-fighting equipment includes two monitors and two foam distributing heads served by the pumps to which allusion has already been made, and, in addition, a portable diesel-driven fire pump is carried, together with two portable 70-ton-hour electric pumps for salvage duties.

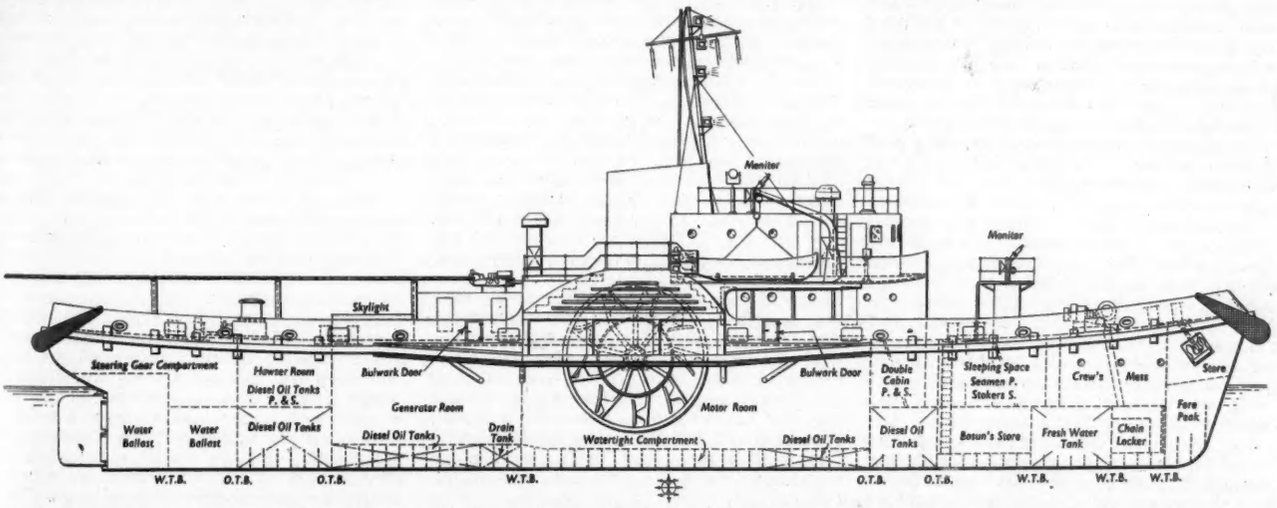
Two 16ft lifeboats are carried on the bridge deck, the davits being of "Schat" single-arm radial type, with hand-operated lifting and turning-out gear.

Heating throughout is by panel electric radiators, while a secondary method of heating in the principal compartments is supplied by slow combustion gas stoves. A plentiful supply of hot water for cabin, galley, pantry and bath room use is ensured by a 50-gallon electric calorifier circulating system, while an oil-fired boiler is in the galley for secondary use. Communication throughout the vessel is by voice pipe, with sound-powered telephones between wheel-house and engine-room. Two signalling projectors are carried and the vessels are fitted for echo-sounding. Ship ventilation arrangements include a motor-driven fan which ventilates general accommodation, and fan exhaust from galley, pantry and bath rooms. The refrigerator is of standard domestic-automatic type. The engine-rooms are well ventilated by motor-driven supply and exhaust fans, while a separate set of fans is provided for the supply of cooling air to each propulsion motor.

On a demonstration cruise on H.M. tug "Dexterous," on March 21, opportunity was afforded to notice the manœuvrability, which was definitely superior to that of one of the screw tugs, in that the vessel pivoted on her centre. She was accompanied throughout the cruise by H.M. tug "Director," which herself gave an exhibition of performance which was very convincing. It is claimed that on occasion one of these paddle tugs can do the work of two of her screw-propelled sisters.

The way in which these vessels can handle commercial ships was proved on March 20, when the Admiralty undertook to help the Cunard liner "Queen Mary" from her berth. Six tugs were sent from Portsmouth dockyard, three screw-propelled and three paddlers, the latter being the "Director" the "Dexterous" and the "Sprite," one of the most recent of the steam-paddle tugs. The new vessels proved most serviceable, raising the question as to whether the paddle tug is not the most suitable craft for all harbour work.

The next paddle tug will be named "Forcible," and it was anticipated that she would come into commission in July at the earliest, but with the present state of affairs it is idle to assign dates. From what has been seen it would appear that the Admiralty was well advised to revert to paddle propulsion. Fig. 5 shows the general arrangement of these tugs.



Length overall (including fenders), 156ft 8in; length between perpendiculars, 145ft 0in; breadth moulded, 30ft 0in; depth moulded, 15ft 0in; draught, full load, 10ft 0in

Fig. 5—General arrangement of diesel-electric paddle tug

Advanced Aeronautical Education

A conference of the Royal Aeronautical Society recently discussed graduate and post-graduate training; there was a widely voiced demand for more and better trained men to become the leaders of the aircraft industry. Liberal education, particularly ability in communication, was esteemed. The needs for a Higher National Certificate in Aeronautical Engineering and for more technicians were also stressed.

THE Royal Aeronautical Society held a Conference on Advanced Aeronautical Education at the College of Aeronautics, Cranfield, last Saturday and Sunday. The chair was taken by Professor A. R. Collar, chairman of the Education Committee. The president of the Society, Mr. E. T. Jones, opened the proceedings by remarking that a "Viscount" sold for £10 per pound; only watches and cameras sold at a higher price. This country must make sure it did not lose the market for aircraft, as it had for watches and cameras.

Mr. R. L. Lickley then gave his views on the industry's needs. He pointed out that many other industries drew upon the advances made by the aircraft industry, and therefore staff of the highest quality were required. The material for advanced education should be men with good academic and practical training, and the instructors must have recent practical experience of their subjects; this might require that there was an interchange of staff between industry and the educational establishment.

He then proceeded to discuss the status of the College of Aeronautics. It had been started by the experts of the industry, and had done a good job, but the quality of the entrants had been unfavourably affected by the desire to reduce the running costs of the college per student—which were not widely different, per student, from those of a particular approved school. The result was that the quality of the students had steadily declined, whereas it should have advanced ahead of university progress, and many of them had no idea of what their place would be in industry. A retrograde step had been the introduction of examinations, which had been caused by the low standard of the entrants, and was unsuitable for a college teaching men to ask "Why?" rather than "How?" The future policy of the college should be to train fewer and better students, particularly as the expansion of graduate training relieved the pressing demands of industry. Unless the college carried out really advanced post-graduate work the necessity for its existence could be queried.

Turning to the aircraft industry, he said that it included 13,000 apprentices, of a higher quality and representing a higher proportion of the total strength than those of any other industry save for certain electrical firms. He believed that the industry needed between 100 and 120 post-graduate recruits every year; these men should be trained on design, fluid dynamics, or applied electronics—he excluded production engineering, since the universities had not found a satisfactory method of teaching it and there was probably not widespread acceptance in industry of college-trained production experts. For these post-graduate men to be satisfactory, it was essential for the teaching of mathematics at every stage from school onward to be completely sound.

The elaborate equipment needed for training at the advanced level could only be justified if it was also used for research work, and to do so had the advantage that a larger staff could be maintained at the college. The need for this equipment, and for there to be an airfield, ruled out the possibility of having more than one establishment carrying out this training. He regarded as an excellent example of such an institution the Cornell University and its Aeronautical Laboratory, and commended their system of having a separate research institute which also carried out design work for outside agencies.

He was in favour of the establishment of a Higher National Certificate in Aeronautics.

The subsequent discussion was opened by Mr. H. H. Gardner, who attributed the absence of college training in production engineering to the high degree of collaboration between college and industry required; it was clear that industry must bear the burden of the training, but staff to do so were acutely short. The diplomates of the college were very useful to the industry when working in their own speciality, but their standard could and should be raised. He accepted the figure of 120 for the annual requirement, but considered that mathematics was a fundamental requirement only of some; for others English was more important. He considered that the two-year graduate apprenticeships current in the industry had been a failure, due to a lack of formal training, and considered that short college courses in specialised subjects would be a valuable inclusion.

Mr. Cherry, head of the faculty of Economics and Production Engineering at the college, pointed out that the course in his department included financial control and similar subjects and corresponded to the courses in industrial engineering in the United States, although the standard was higher. Such courses totalled 8000 students in the U.S., but less than 100 here. The short time lag between design and delivery in the States was due to the efforts of these engineers, and more trained production engineers were a necessity here.

Sir Roy Fedden considered that the Society were only belatedly taking an interest in advanced education. The college, certainly, had not progressed as well as it should have, but among the reasons were a lack of support from the industry and the Society and jealousy on the part of the universities; it had been intended to erect a special building, but in the event an R.A.F. station was used. Recent years had certainly not been vintage years for British aircraft, and the reason was the lack of the right type of people in the industry; this would only be rectified when it was regarded as affording a magnificent profession with "snob value." Maths. was an essential for the scientist, but the aircraft industry lacked mechanical engineering ability; in this country there were 105 scientists but only forty-five technologists per million people. Nor were the engineers sufficiently highly trained; over the last ten years the British industry had 1·9 per cent of staff with research experience against 9 per cent in the U.S.A. The time to produce the finished article was critical, and engineering ability was the deciding factor here. In Germany and the United States there were university chairs of great prominence in production engineering, but in this country there was at present not one professor of production engineering. Production engineering was a highly advanced and essentially post-graduate study and one that the college should prosecute.

Mr. H. Lomas pointed out that most first-class graduates remained at their university for post-graduate courses, and advocated that the college should accept students with a convincing Higher National Certificate endorsed for mathematics and aero structures. Deficiencies in mathematical training were the result of the qualifications established by the Society and the Institution of Mechanical Engineers. He recalled that as early as 1951 the Society of British Aircraft Constructors had suggested to the Society that there should be an H.N.C. in aeronautical engineering.

Professor A. D. Baxter pointed out that it was the industry, being free to offer any salary to any individual, which could determine whether or not there was an interchange of staff between firms and the college, and similarly it was the industry that chose not to employ graduates on production engineering. If those leaving the college expected industry to be different from reality, as Mr. Lickley said, it was because firms anxious for their services evoked unrealistic prospects. He remarked that before examinations were introduced at the college, the Society had not recognised the diploma as an exempting qualification.

Mr. Lickley refuted the last speaker, believing that the interchange of staff between industry and the college was in fact taking place. He considered that the outlook of the college students had at one time been less objective than that of university alumnæ.

Mr. H. A. Mettam then gave a lecture on the Scientific Civil Service: post-graduate education was limited to courses in engineering drawing and electronics and to evening classes on such subjects as statistics. Scientific officers were unable to undertake full-time studies for higher qualifications.

Mr. M. B. Morgan drew attention to the two applications of advanced education—stretching the ability of the individual to a higher level, or broadening his knowledge to cover a wider field. He considered that the experience of actually executing research work was of terrific value, and suggested that graduates would benefit greatly from visiting foreign universities to do research work.

Professor H. B. Squire drew attention to the series of articles in THE ENGINEER on engineering education in the Soviet Union,* and pointed out that since the degree course was shorter in this country, there was a correspondingly greater need for post-graduate education. In his experience, not more than one-third of graduates were able to benefit from further study; the remainder had reached their ceiling. In aeronautical engineering, if not in other branches, the best occupation for graduate students was an individual job of research work. The proposed arrangement of people spending, say, five years in industry and five in teaching simply would not come to pass; men with families would not move to satisfy some vague national need. We must not expect any such interchange and, therefore, either advanced courses must be restricted to fundamentals, or the teaching staff must spend part of their time working in industry, as was the practice in Germany and Switzerland. These were the only two methods by which satisfactory research could be conducted.

Professor W. Fiszdon believed, on the basis of his experience at the Polytechnic, Warsaw, that an active connection with a firm was not beneficial to a teacher.

Group Captain J. R. Morgan described the training of Royal Air Force technical officers; those required for research and development duties or special appointments received advanced training at the college or, for electronics, at Southampton University.

Professor E. J. Richards said that in teaching a student at advanced level for a future career in research, design or production, it was more important to infect him with the research bug or spirit, the design spirit or the production spirit, than it was to cover every technical aspect of the subject. And for this reason, it was essential that the staff engaged were able to provide this infection. It was a vital point in the discussion of education to see how the staff can be kept in the right environment. Like Professor Squire, he did not believe that in this country the principle of periodic interchange could be fostered; the rewards were too small. But every university can and should build up active research groups to foster the environment of research; they should also encourage very close integration of joint courses with industry to foster the environment of design and development among the staff, and even tie up with industry on production problems. It was the vast chasm between university and production thinking and environment that had caused so much lack of trust of universities by production men.

On the side of research, this suggested that we as a country should go for many small university teams rather than set up one large research "sausage machine" at one place, as Mr. Lickley had suggested earlier. And to do this help was required from industry. They enticed men away from post-graduate university systems by offering large financial inducements. Staff found experimental research difficult because of the time needed for their teaching commitments. Industry should therefore consider it a basic requirement in order to keep the right teachers at the universities, to award them research fellowships to provide full-time assistance on research and to allocate from time to time men from industry to work with the university research teams. They should also award (as does the Ministry of Supply

* February 8 and 15, 1957.

so successfully now) vacation consultancies to the staffs of higher colleges of learning to infect into these men the right spirit to teach design and production to the students. Unless this was done, there was a grave danger that the expansion of technology will be stunted by both the lack and poor quality of its teachers.

Professor A. J. Murphy pointed out that, because of the high standards achieved at school, 95 per cent of undergraduates actually took three-year courses, and such a course was too short ; if the full four years were utilised more basic studies could be included. This country was alone in attempting to reach honours standard within three years of leaving school, and that standard was not lower than that of the United States or Germany.

Professor A. D. Young drew attention to the fact that there were only just 120 men graduating in aeronautical engineering each year, so that first-class degrees would number perhaps twenty or thirty ; thus Mr. Lickley's postulated requirements could not be met. Even Cambridge University, to enter which there was a competitive examination, turned out many third-class graduates, so that selection would not give an increase in first-class men. However, he did not think there was such a great need for top-grade students ; the biggest gap between supply and demand was probably at H.N.C. level, and at present many graduates in industry were doing work that needed no more than a school education—a more rational use of men by firms would allow the figure of 120 to be reduced. Since it was the second and third-class students to whom teaching was a necessity, they should have an opportunity to enter the college. The fact that our courses lasted three years, instead of the five or six prevalent on the Continent, meant that a degree alone was inadequate.

Mr. N. E. Rowe agreed that graduates were often not fully exploited. It was the practice of Blackburn and General Aircraft, Ltd., to move them from one job to another every six months for five years. To provide the right environment for research students in universities, he favoured the staff engaging in active consultancy to gain acquaintance with the challenging problems of the time. Referring to the shortage of graduates, he pointed out that those who had taken courses other than engineering might well have done so because they lacked mathematical ability, so that they would not be a potential reserve for the industry.

The next session was devoted to a lecture by Mr. A. J. Jenkinson on the need and scope for a liberal education ; it was heard with undoubted pleasure and great attention, but in the discussion the view was voiced that engineering was still sufficient of an art for there to be no need for guilt over the absence of avowedly artistic studies.

On the following day proceedings opened with a paper by Professor A. J. Murphy on the place of the College of Aeronautics in advanced education ; he commenced by observing that the college was unique in this country in providing access to advanced study without passing through undergraduate training. The initial interview with prospective candidates was tending to become an oral examination. The first term at the college was really occupied by the student orienting himself, and at the end of it he selected a major and a minor specialisation ; most of his second year would be devoted to the major subject. The divisions in the past had been :

	Per cent
Aerodynamics	27
Design	25
Propulsion	20
Economics and production engineering ...	18
Electrical	10

It had been said that the standard of entry had deteriorated ; but the board had not consciously lowered their standard. This he confirmed with figures showing the proportion of graduates over nine sessions, and by the proportion of applicants accepted, which had averaged 72·3 per cent over the last five years and was 72·6 per cent last year. However, the trend was probably towards a smaller proportion of graduates, because of the creation of fresh channels to qualifications such as the Diploma of Technology.

The unusual procedure of instructing holders of degrees and Higher National Certificates on the same course required appraisal. Passes were divided into three classes, and the percentage of graduates in first, second and third was 26, 38, 24, and of certificate holders 12, 36, 37. The fact that the proportions in the median class were the same convinced him that a single course for both classes of student was satisfactory.

The college also conducted short courses, lasting between four days and three weeks, including one for N.A.T.O. on guided weapons. The short courses, however, were disproportionately expensive in directing staff effort.

The numbers of students were increasing and the intake would rise from 100 to 150 each year. The course was best suited to honours graduates in mechanical engineering, but graduate aeronautical engineers were accepted into the second year.

He emphasised that the college was in no competition with the universities, and wished to see the faculties of aeronautics flourishing. Nor did the college desire to rob universities of prospective research students.

The next speaker was Professor A. V. Stephens. He reminded the meeting that advanced education was required to provide leaders for the industry, not useful technicians, and the essential was that the student should be heartily convinced that any result he obtained was solidly based on fundamentals. The students must work in contact with staff of intellectual integrity, and experimental work must be performed with integrity. The work must leave certain matters to the judgment of students, in order to exercise that faculty.

The intense specialisation that occurred after a man left college meant that he would forget 90 per cent of what he had learnt, and the appropriate habits of thought were his principal benefit. If more was taught in the course, it might mean that 95 per cent was forgotten. Engineering was a more exacting occupation than pure science, requiring great patience and assiduity, and to work out realistic problems a vast amount of time was needed. The course work must leave scope for ingenuity in order that that quality, which was so important to the subsequent employer, could be assessed.

He went on to recall the course he had conducted at Sydney University. Students entered at seventeen and took a four-year course, but in the case of superior students a fifth year achieved a B.Sc. in addition to the B.E. degree. The pure science and mathematics subjects were taught by the science departments, and since the engineers did these subjects in addition to their own, the Sydney schoolmasters sent only able and industrious pupils to the course. The third year consisted of two terms and six months' practical work ; whether the students performed responsible or routine work appeared to affect the results little. A comprehensive report on this activity was required, and the need for it caused students to exercise their observation and judgment.

His view was that research work should be taken seriously, to the extent that the student was regarded as a by-product. He would employ no staff who did not engage in research, and some who did nothing else. But the teaching of such subjects as design might well be done best on a part-time basis by engineers from the industry. He considered that the overwhelmingly important decision was whom to take in and teach.

Mr. A. A. Part presented some views of the Ministry of Education. He held that the "bulge" in the birth-rate was less important than the "trend" for pupils to stay later at school ; the number of pupils aged seventeen was increasing 5 per cent per annum, having been 30,000 in 1950 against 50,000 to-day. This meant that in the late 1960s the universities would have 80 per cent more prospective candidates and not the 15 per cent more due to the "bulge." He asked what was the basis of the figure of 120 or 150 post-graduate trainees required per annum.

In the resumed discussion, Mr. L. W. Rosenthal endorsed Mr. Lickley's complaints of the engineers leaving the college. The college was intended to fit them for leadership ; what did the college do to this end ? What questions were asked in the oral examination to assess potential leadership ? Leaders were hard to find, perhaps 2 per cent of a sample being suitable material. The greatest need was not for more graduates but to give them better leadership, and leadership was more important than mathematics on a post-graduate course ; the instructors should be chosen for a spirit of leadership. In selecting students, their attitude to responsibility should be assessed, and to do this it might be necessary to examine their domestic background—he believed that the sons of responsible professional men should be preferred.

Short courses were, at present, difficult to utilise because they were not programmed twelve months ahead ; the Society should act to bring this about.

Mr. J. S. Tait observed that the industry could absorb all the students turned out of the colleges, but was concerned over their less scholastic merits. The conference had heard nothing to influence syllabi. The ability to participate in the use of the test facilities at Cranfield was invaluable to such colleges as the Northampton Polytechnic, particularly as fresh airfields were obviously out of the question.

Mr. H. Lomas did not favour the assignment of university honours standard to the Diploma of Technology. There was not, he asserted, a lack of training facilities at university standard ; the courses were not full. If the student held the necessary qualifications, he could be sure to enter a university, and by that method he qualified more rapidly. The diploma should be treated as an opportunity to liberalise technical education, and the standards for entry to a four-year sandwich course could well be lower than for a university. He also recommended that the length of the course should be so adjusted that the entrants to the college from different sources were all of the same age.

Miss A. Kennedy observed that there were relatively few women students, and asked what educational background they had.

Mr. J. F. A. Radford held that the demand for graduates of quality laid additional emphasis on sixth form study. The recruitment of graduates by D. Napier and Son, Ltd., had been increased substantially by approaching pupils of sixteen and offering to sponsor them for a degree course, provided that they studied in the sixth form pure and applied mathematics, physics and English, not merely the minimum of subjects. The assistance of the college principal in selecting candidates had been found beneficial, while in the case of students doing sandwich courses one and the same tutor must work with the man throughout.

Mr. R. J. H. Isaacs emphasised the need for literacy ; he held that H.N.C. holders were weak on fundamentals, and that any increase in the amount of instruction should be devoted to underlying principles and to the means of expression.

Sir Victor Goddard recalled the early history of the college. The leading practitioners of any art were usually found to distrust and oppose new proposals ; but, in fact, young, bright, new, and fundamentally sound projects should be encouraged. This was true of education. The college had originally been severely unwelcome, and that it had survived was due to the fact that it could draw suitable students from wherever they were found.

The fighting services had found that Staff College trainees benefited most if they were in the age group twenty-seven to thirty. This explained the opposing views of Mr. Lickley and Professor Murphy on the quality of the college trainees ; Mr. Lickley's pupils in the early years were about thirty, and benefited more from the course. He advocated a true post-graduate course as distinct from graduate continuation training ; to attract students of the right age it would be necessary to provide married quarters, even as at Staff College. To encourage men to take the courses, employers should commit themselves to re-employing them afterwards.

He warned against the invariable trend of leaders towards conservatism.

Sir Roy Fedden reiterated that the need was to produce hardware. The industry needed 150 post-graduate recruits each year if it was to be successful ; there could not be too many aeronautical engineers, because they were capable of rendering valuable service to any other

industry. He stressed that if the problems of higher technical education were not overcome in fifteen or twenty years this country would fear, not the hydrogen bomb, but starvation.

Mr. H. H. Gardner inquired of Mr. Part whether the 50 per cent of children studying science were the top 50 per cent; he suspected not.

Mr. R. L. Lickley explained the derivation of his figure for the industry's annual needs. The apprentices comprised 8700 trade, 3400 engineering, 500 student, and 300 graduate. None of the first, one-quarter of the second and third, and one-half of the fourth class made a total of 1200 ; 120 was 10 per cent of this.

Mr. D. M. Bonfield was also in favour of a delayed post-graduate course, possibly six months long and taken eight years after entering industry. Students such as would attend a course of this nature would give the staff a very clear picture of the needs of industry.

Mr. C. M. E. Warren endorsed a course attended between the ages of thirty and forty. The progress of aeronautics was so rapid that, a few years after graduating, engineers were no longer equal to productive work, and must be assigned to supervision.

Mr. A. A. Part discussed Mr. Rosenthal's views, and observed that the "means test" for financial support for undergraduates had been altered in favour of dependents of professional men. The next three-yearly review of this test was soon due, and it would be seen if this trend continued. On the other hand, technical colleges benefited from this means test, as they received students who would otherwise have attended a university.

Mr. Gardner's views were pessimistic ; the trend towards science in schools was so strong that some masters were alarmed! There were not places at universities for all who wished to attend, and over the next few years the Bulge and the Trend would emphasise this. Referring to the scarcity of women observed by Miss Kennedy, he predicted that the bulk of the women would enter the industry in laboratory occupations rather than as engineers, at least for the next ten years.

The Chairman then summed up the discussion. The Society had a long record of attempts to introduce a Higher National Certificate in Aeronautics ; its proposal in 1938 had been turned down flatly. They had tried again unsuccessfully in 1946, before its Charter laid upon it a duty of education, and they were even now active in discussion.

The liberalisation of education should begin in the schools ; dichotomy between arts and science in school was unnecessary and undesirable. Engineers should be drawn from the pupils in the middle who had taken both English, history, and mathematics, and science. At Bristol University honours students were required to pass an examination in English ; the course on the use of language, conducted by an arts teacher, had been found stimulating.

He was surprised that contributors had asked that students should be inculcated with humility ; in his experience they were humble, and he could not imagine any trained engineer being otherwise.

The Bristol Aeroplane Company had for many years sponsored a 1-3-1 sandwich course ; he found that the first year, spent in the industry, was an astonishingly useful preliminary to the university work. A four-year degree course had great advantages, but it also had financial and social drawbacks ; however, it was bound to come, and the scope of the instruction should then be broadened.

Post-graduate work at universities would continue to be mainly research ; there was a need for advanced instruction, and that should be carried out in a year at the college. The second year of the complete Cranfield course was invaluable to an aeronautics graduate, particularly for the study of design and structures.

The training of production engineers was vitally necessary, and merited an enormous amount of attention. He advocated a post-graduate study for one year after a 1-3-1 sandwich, because some experience of industry was essential for the student of production methods. The formalised instruction available at the college should be exploited. He related that one of his colleagues regarded production engineering as "common sense" ; another had declared himself in favour of post-graduate courses in common sense.

Five-Ton Mains-Frequency Coreless Induction Furnace

A mains-frequency, coreless induction furnace with a capacity of 5 tons, the first industrial installation of its kind in this country, was commissioned recently in the foundry of International Combustion, Ltd., at Derby. It has an electrical rating of 300kW and it is to be used mainly as a holding and superheating furnace in the production of spheroidal graphite cast iron. A brief description of the furnace is given here.

RECENTLY we visited the foundry of International Combustion, Ltd., at Derby, to see the first mains-frequency coreless induction furnace to be installed for operation on an industrial scale in Great Britain. This installation consists of a 5-ton furnace of 300kW rating with the associated tap-changing transformer for control of the electrical input, static balancer for approximately equalising the three-phase loading, and condensers for power factor correction.

The furnace was manufactured and installed by Birlec, Ltd., Tyburn Road, Erdington, Birmingham. In describing it as the first industrial plant of its kind in this country we should recall that a small experimental mains-frequency Birlec furnace, with a capacity of about 18 cwt, was installed at the Coventry works of the British Piston Ring Company, Ltd. Later it was transferred to International Combustion, Ltd., where it has been used for melting ferrous and non-ferrous metals. In September, 1956, it was announced that Birlec, Ltd., had made an agreement with Otto Junker G.m.b.H., of Lammersdorf, Germany, and the Ajax Engineering Corporation of America, for the development and marketing of this kind of furnace, which had been pioneered over a number of years by Junker in Germany. In October, 1956, Birlec exported a 5-ton holding furnace of this design to India for installation at the Jamshedpur foundry of the Tata Engineering and Locomotive Works.

The main function of the new furnace at International Combustion is the production of spheroidal graphite (s.g.) cast iron to be used in place of steel castings and complicated steel forgings which at present form components of pulverising mills, powdered fuel burners, coal feeders, travelling grate stokers, spreader stokers and various components of grinding, screening and filtering plants. S.g. cast iron has already been used for prototype castings such as mill roller arms, stoker driving gearbox worms, gear wheels of various sizes, grinding rolls and similar parts ; the results, both from the point of view of production and of prolonged life, are promising, and it is proposed to extend the application of this ductile iron to include every component where the form indicates a casting and the function indicates a high-duty metal. The component parts selected for production in this way are already being redesigned to make the fullest use of the new casting technique and there is no intention of merely changing the specification of the iron and using the same patterns and casting routine.

Other uses of the furnace will be the production of chrome iron and stainless steel castings ; they have fewer applications and metallurgically are less interesting, but nevertheless have their place in certain specialist equipment produced by International Combustion, Ltd.

Although the furnace is intended primarily as a holding and superheating unit, being fed from cupolas, it has a useful melting rate with cold additions and enables a number of metallurgical operations on special irons to be carried

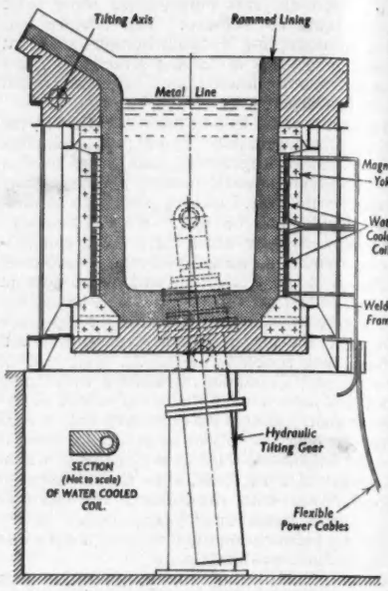


Fig. 1—Cross section of mains-frequency, coreless induction furnace

out which could not be performed in either a cupola or a core induction furnace.

Between temperatures of 1350 deg. and 1550 deg. Cent. the superheating rate is about 5 tons per hour per 100 deg. Cent., with an approximate power consumption of 60kWh per ton, and the melting rate is approximately 8 cwt per hour with power consumption of 670kWh per ton. This latter figure may appear to be rather high, but it should be remembered that the furnace body is large, primarily designed for superheating and holding hot metal and not for melting;

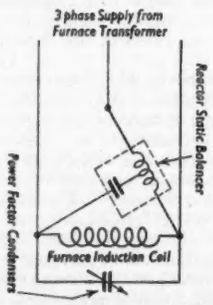


Fig. 2—Basic circuit for balanced three-phase supply to induction furnace

therefore, the electrical input at 300kW is small in relation to the furnace size.* This modest loading reduces the melting rate and therefore increases the energy consumption per ton to be melted.

The basic principles of the mains-frequency, coreless induction furnace† (Fig. 1) are similar to those of the high-frequency furnace. The melting chamber or crucible, which is cylindrical and lined with a rammed refractory, is surrounded by a helical water-cooled copper coil, through which a heavy current is passed to induce the necessary heat in the charge. The

* For comparison the small experimental furnace mentioned above has approximately the same electrical loading for less than one-fifth of the charge capacity and is, therefore, more suitable for melting.

† THE ENGINEER, November 11, 1955.

furnace can be considered as a simple transformer with the charge forming the secondary coil. In furnaces of capacities larger than about 15 cwt it is practicable to supply the coil with current at 50 c/s (instead of at frequencies between 1000 and 10,000 cycles) with considerable economies in running costs. The 50 c/s current induces a marked stirring action in the bath, ensuring that the whole depth of molten metal is at uniform temperature and analysis.

Fig. 3—Birlec 5-ton mains-frequency, coreless induction furnace. It is rated at 300kW and is being used for holding and superheating high-quality grey irons and spheroidal graphite iron in the foundry of International Combustion, Ltd., Derby

The new installation consists of the furnace itself, mounted in a surrounding charging and operating platform which also carries the pouring controls, and a substation, situated immediately behind the platform, containing the electrical equipment for supplying the furnace with power. Behind and above the furnace is the foundry laboratory, which is so situated that the furnace can be viewed in operation and samples can be analysed with no loss of time.

The induction coil is a helix wound from a specially extruded section of the general form illustrated (but not to scale) in Fig. 1, with a cylindrical passage for the cooling water. The section, which was extruded in Germany under the Junker agreement, is designed to minimise skin effect. Glass tape impregnated with silicon varnish provides the coil insulation. The coil is supported and restrained axially by spring-loaded end rings and radially by packets of transformer iron laminations which provide a return path for the magnetic flux and permit the use of a solidly welded steel outer casing. To protect the coil during relining operations there is a cylindrical asbestos board shield (not shown in Fig. 1) between the coil and the refractory lining.

The initial lining of the furnace described here consists of a high-silica refractory rammed round a sheet steel former that is melted out with the first charge, thus sintering the lining. When melting iron with a pouring temperature approaching 1500 deg. Cent. the life of such a lining is stated to be about 150 heats.

The furnace is tilted for pouring (Fig. 3) by hydraulic rams, one on each side of the body (Fig. 5). They are supplied with fluid by a vane pump controlled by a valve mounted on the control stand on the furnace platform. The rams are of large diameter using low operating pressures to give smooth and progressive tilting action with mechanical rigidity. The normal pump is driven by an electric motor, but an auxiliary petrol motor driving a standby pump is provided for use in the event of a power failure. Limit switches are fitted to cut off power to the coil at the start of the tilt and to switch off the pump motor at the maximum tilt position.

The present installation operates from a low-tension supply of about 420V, which is fed to the equipment through a contactor and an isolator that is mechanically interlocked with the substation access door and with the entrance to the furnace excavation. Access to the substation is only possible, therefore, when power is off. The main on-load contactor is provided with overload protection, backed up by H.R.C. fuses and an off-load isolator. It is a three-phase unit mounted on the supply side of the static balancer. The transformer is provided with adequate tappings to ensure a wide range of power inputs, so that any degree of superheating or melting, up to the maximum, can be achieved. In the substation there is also a reactor associated with a static balancer to give a reasonably balanced three-phase load on the incoming supply mains.

For correction of the overall power factor a bank of 50 c/s capacitors is provided, connected in parallel across the coil. The capacitors are housed in the substation (Fig. 4) immediately behind the furnace platform. A simplified diagram showing the elements of the three-phase balancing circuit, but omitting the contactors and isolators is given in Fig. 2.

Current is brought to the furnace from the busbars by water-cooled flexible cables and coil cooling water is brought by flexible hoses. The water supply is controlled from a cabinet below the instrument panel and monitoring relays are provided which shut off power and give warning in the event of inadequate flow. As the furnace coil would suffer damage if the water supply were interrupted for more than a few minutes while the furnace was hot, an emergency water supply is provided.

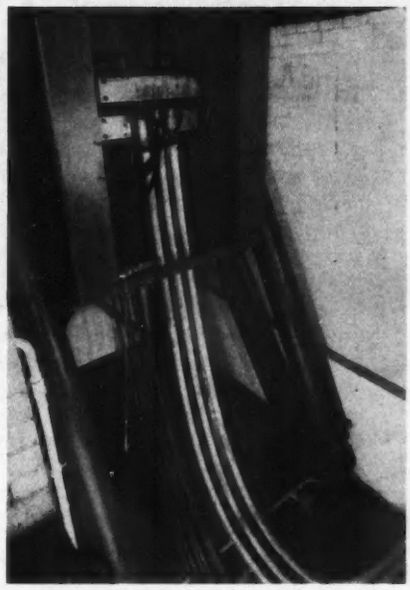


Fig. 5—Foundation pit of mains-frequency, coreless induction furnace with back plates removed to show busbars and water-cooling supply pipes

The transformer, which can be seen on the left of Fig. 4, was supplied by the Woden Transformer Company, Ltd., Bilston, Staffs, and the capacitors for balancing and power factor correction by British Insulated Callender's Cables, Ltd.

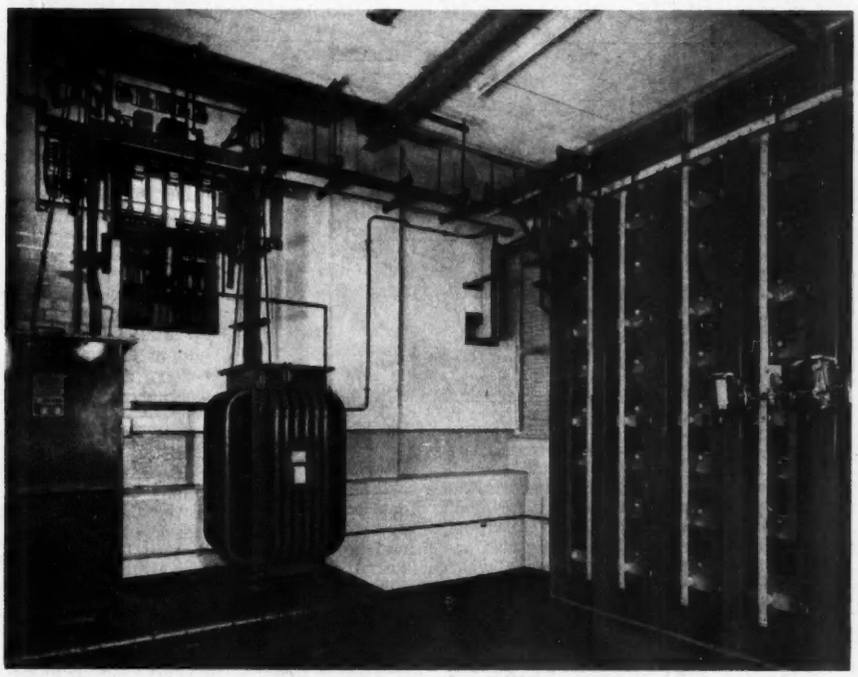


Fig. 4—Substation for mains-frequency, coreless induction furnace. On the left are the static balancer reactor and transformer and, above them, the water control cubicle. On the right are the capacitors and busbar connections to the furnace

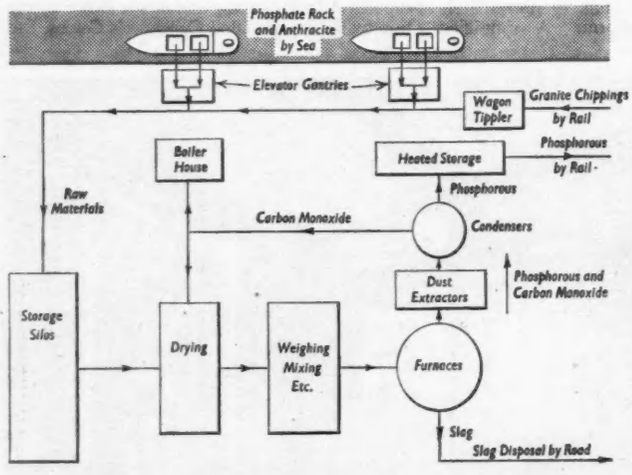
Electrical Machinery in a Phosphorus Factory

The factory for manufacturing phosphorus, illustrated on the right, has been established at Portishead by Albright and Wilson, Ltd. It has an annual output capacity of about 40,000,000 lb of phosphorus, and provision has been made for considerable expansion, if required. Briefly, the manufacturing process consists of mixing calcium phosphate with silica and carbon in an a.c. furnace, where the silica displaces phosphoric oxide and forms calcium silicate which is removed as liquid slag. The phosphoric oxide is reduced by the carbon, yielding phosphorus vapour and carbon monoxide, which are then separated in a condenser. There are six electric reduction furnaces with a total maximum demand of 45MW and the aggregate horsepower of the motors installed in the factory is 5000 h.p. Below we describe some of the electrical plant supplied by The General Electric Company, Ltd.

A NEW factory for the production of phosphorus has been set up at Portishead, Somerset, by Albright and Wilson, Ltd. The factory site on the Bristol Channel has two important advantages—the existence of good dock facilities for the delivery of raw materials by ocean-going freighters, and the proximity of Portishead power station to meet the electrical demands of the factory, which has an installed load of nearly 50MW.

The Portishead plant has an output capacity of 40,000,000 lb of phosphorus per annum, which is more than the total previous output of the United Kingdom. At the same time, the factory has been so designed that its output can be greatly increased at short notice if required. Much of the phosphorus produced at Portishead is transported by rail to another new Albright and Wilson factory at Kirby, near Liverpool, where it is converted into phosphoric acid and sodium tripolyphosphate—a compound which is incorporated in non-soapy detergents; we learn that the output of this substance from the new plants will entirely replace imports which, in 1953, amounted to more than £2,000,000 in value.

The manufacturing process is the one normally used for the industrial production of phosphorus. It consists, essentially, of the mixing of calcium phosphate with silica and carbon in an a.c. furnace where, at high temperature, the silica displaces phosphoric oxide and forms calcium silicate which is run off as liquid slag. The oxide is reduced by the carbon and the resultant phosphorus vapour and carbon monoxide are then passed over to a condenser, where they are separated. Six furnaces are installed in the Portishead factory. From the simplified flow diagram it will be seen that the carbon monoxide extracted in the condensers is used as a fuel in the drying plant and boiler-house.



Simplified flow diagram for the Portishead phosphorus factory

Handling of Raw Materials

The main raw materials used in the Portishead factory are phosphate rock and anthracite, which are brought to the plant by sea, and granite chippings, which are carried by rail. Both the phosphate rock and the anthracite are in a form which makes them suitable for handling by pneumatic plant. Unloading of vessels is therefore carried out by two mobile elevator gantries carried on rails along the length of the quay. These elevators can operate simultaneously and independently, each being provided with suction pipes which are manœuvred and lowered into the hold of a ship by winches mounted inside the gantry. The raw material is drawn up these pipes into a hopper on top of the gantry, whence it is deposited on a small conveyor belt which transfers it from the gantry to the main conveyor. This main belt, which runs parallel to the quayside, is completely enclosed except for a series of ports with which the small conveyors on the gantries register when unloading is in progress, as can be seen from our first illustration.

The two suction pumps which produce the vacuum necessary for raising the materials from the holds are installed in a pump-house adjoining the main conveyor; each pump is driven by a 330 h.p., 415V, 585 r.p.m. G.E.C. slipring induction motor, as illustrated below. The elevators are connected to their pumps through pipes mounted beneath the main conveyor and running the length of the quay, the couplings being mounted immediately below each of the ports in the conveyor enclosure.

The incoming granite chippings are unloaded, by a wagon tippler, on to the same main conveyor as the other raw materials. This conveyor leads up to the top of a bank of storage silos comprising eight circular bins, 100ft high, in which the rock is stored, the spaces between the bins being used to store the anthracite and the granite chippings. These silos have a total capacity of 24,000 tons.

On reaching the top of the silos, the material is deposited on to a transverse belt, which, in turn, conveys it to any selected one of three transfer belts. Each of these belts is mounted on a motor-driven, wheel-mounted carriage running on rails across the tops of the silos, as illustrated below. The carriage may be stopped at registered positions such that the belt discharges into the top of the selected storage space, the cover of which opens automatically when the belt is correctly located.

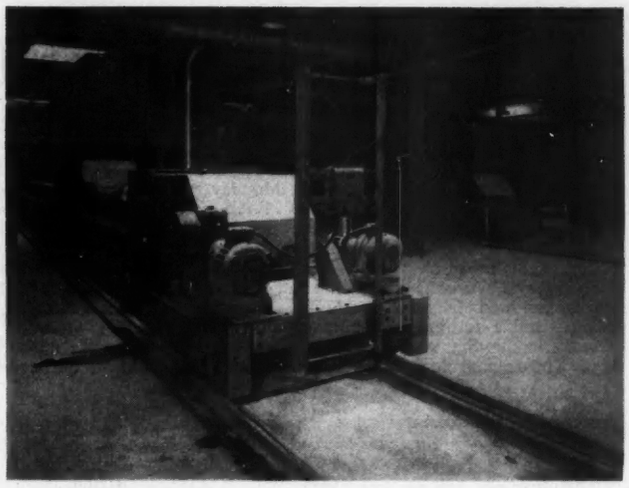
The unloading of the cargo vessels and the transference of the raw materials to the silos is done automatically. In a control room at the top of the silos is a control panel on which is a diagram showing which of the conveyor belts are in operation. The belt drives are electrically interlocked in sequence so that no belt can be started until the one before it is running. In an emergency, any section of the conveyor may be stopped by means of switches operated by hand ropes which are installed along the full length of all the belts. If any particular belt is stopped, all those preceding it are automatically stopped at the same time, while those following it continue to run until they have cleared all the material they are carrying at that time.

When the raw materials are removed from the storage silos for use, they are first dried in calciners, which, as previously stated, use as a fuel the waste gases extracted in the condensers. The materials are then automatically weighed and mixed, and the mix is carried, by belt conveyors, to hoppers at the top of the furnace house, whence it is fed, by gravity, into the furnaces.

Furnaces

In the furnace house there is a bank of six electric reduction furnaces, each capable of a maximum loading of 7500kW. In most respects, the furnaces are of orthodox design. The main shell is fitted with a slightly arched roof, the sides being lined with a suitable refractory, and the base with carbon. A tap hole is provided through the carbon lining to allow the withdrawal of slag. The electrodes pass through the roof, which also carries the feed spouts and the offtake

Pump-house in the Portishead phosphorus plant. On the left is a 300/330 h.p. slipring motor driving one of the two suction pumps connected to the elevator gantries



Top of storage silos at Portishead. One of the three transfer belts is shown here. It is fitted with 3 h.p. and 5 h.p. motors with external cooling fans

for the phosphorus vapour and carbon monoxide.

Each furnace is supplied from a pair of 4140kVA, three-phase, furnace transformers, installed in a separate brick-walled enclosure at the back of the furnace platform. The delta-connected primary winding of each transformer is supplied at 11kV from the h.v. switchboard in the works substation, while the secondary winding is connected in star to give an output of 7300A at 180V no-load. Secondary voltages ranging from 100V to 230V can be obtained by means of two off-circuit tapping switches, one providing coarse and the other fine adjustment. The tapping switch handles are fitted with Castell locks, the key of which is also used in a Castell switch. This switch is arranged to trip the associated circuit breaker in the substation before the key can be withdrawn, and the breaker cannot be reclosed until the key is returned. An indicating lamp is provided to show when the circuit breaker is in the tripped position.

Cooling of the transformers is by radiators, comprising banks of cooling tubes of elliptical cross-section, fitted to the sides of the tanks. Cooling air is forced upwards over the tubes from holes in the floor beneath the radiators, these holes being connected, through trunking, to fans driven by 10 h.p. motors on the floor below. The connections between the transformers and the furnace consist of tubular copper busbars and the necessary supplies for metering and control equipment are provided by ring current-transformers threaded over these conductors. Control boards for each of the furnaces are sited at the back of the furnace platform, the equipment being designed to maintain a constant furnace load.

Periodically, each furnace is tapped and the slag is run out into covered ways, where it is allowed to cool before being carted away by road. Any fumes that may be emitted while tapping is in progress are extracted by fans driven by 100 h.p., 960 r.p.m. G.E.C. slipring induction motors. These fans are mounted outside the furnace house at the base of tall chimneys.

The mixture of phosphorus vapour and carbon monoxide, which is continuously drawn off from the top of the furnaces, passes through dust extractors to the condensers. There the phosphorus is cooled to the liquid state while the carbon monoxide is allowed to pass through. Transfer of the carbon monoxide from the condensers is effected by rotary boosters driven by 80 h.p., 1460 r.p.m. slipring induction motors. On leaving the condensers, the liquid phosphorus is piped to heated underground tanks, where it is stored in the molten state.

Electrical Supplies

All the main switchgear controlling the electrical supplies to the factory is housed in a single-storey, brick-built substation which is divided into two main sections, housing the h.v. and l.v. switchgear, respectively, with two small annexes for the battery and metering equipments.

The incoming supply from the South Western Electricity Board is stepped down to 11kV, and is controlled by duplicate-busbar metal-clad 11kV switchgear having a breaking capacity of 350MVA. This switchboard consists of seventeen panels comprising three 15MVA incoming supply units, six 8MVA units controlling the feeders to the furnace transformers, four 4MVA units controlling the primary supplies to the auxiliary transformers, and four bus-section units. Fireproof segregating walls are built between the front and rear bus-section switches on each section so that, in effect, the board is divided into three parts.

The circuit breakers are double-break equipments fitted with side-blast arc control pots. They are arranged for vertical isolation and, when in the isolated position, each breaker can be completely withdrawn on its carriage from the stationary part of the unit, thus permitting maintenance to be carried out in safety. The rectangular copper busbars, which are rated at 1500A, are enclosed in compound-filled chambers of fabricated steel construction, and off-load busbar selection is done by transfer of the breaker. The circuit breakers are arranged for solenoid operation and are controlled from separate panels which accommodate the necessary relays, control switches, indicating lamps, &c. These panels are mounted on the wall opposite the associated units. Facilities for manual operation are also provided for emergency use and for maintenance.

The four 1000kVA auxiliary transformers which step down the voltage to 415V for supplying motors and other auxiliary equipment throughout the factory, are mounted in brick enclosures along one side of the substation. The windings are connected in delta-star, the neutral connection being brought out on the secondary side so that a 230V phase-to-neutral supply is available.

The truck-cubicle switchgear which controls the 415V circuits has a breaking capacity of 30MVA. There are twenty-nine panels, the switchboard being built in two sections which are installed on opposite sides of the l.v. substation. Each panel is equipped with a hand-operated oil circuit breaker, four 2000A units controlling the incoming supply from the auxiliary transformers, and three further units of the same rating employed as bus-section switches. The remaining panels, comprising eighteen 600A units and four 400A units, are used for feeder control.

Each wheel-mounted truck consists of an angle-iron framework fitted with an enamelled steel front-plate on which are mounted the instruments and relays. The oil circuit breaker, instrument current-transformers and isolating plug contacts are supported on the framework of the truck. The corresponding cubicle is built of steel plates and is divided into two sections, the rear compartment housing the busbars and outgoing cables. Apertures in the dividing plates allow the isolating plugs connected to the circuit breaker and current-transformers to pass through and make contact with the corresponding fixed contacts on the busbars and outgoing cable terminals. These apertures are provided with automatically-operated shutters. The 2000A hard-drawn copper busbars are mounted on porcelain insulator supports, the connections between the two sections of the switchboard being carried in sheet steel trunking fixed to the end wall of the substation above the doors leading to the battery and meter rooms.

A panel carrying an indicating mimic diagram of both the h.v. and l.v. switchboards is mounted on the wall of the l.v. substation, the connections between this panel and the switchgear being made with thirty-two-core, 50V cable.

The three-panel switchboard housing the metering equipment associated with the furnaces and the auxiliary supply circuits is installed in a small annexe divided from the l.v. substation by a fireproof, sliding door. Another annexe houses the 110V battery, together with its control board.

For the electrical equipment of the Portishead factory The General Electric Company, Ltd., supplied all the works substation switchgear and metering equipment, the distribution transformers, the furnace transformers with the associated control gear, and many of the motors.

Surveys for Engineering Development in British Columbia.—The Government of British Columbia and the Wenner-Gren Foundation recently signed an agreement for a comprehensive survey of an area in British Columbia between Prince George and the northern border of the province. The area is situated about 500 miles from Vancouver, and is in the Rocky Mountains Rift, and south of the Yukon border. The survey is expected to take about two years, and it aims at investigating hydro-electric power, mining, forestry, communications and transport. The Wenner-Gren British Columbia Development Company, which has been formed for this work, has appointed the British Thomson-Houston Export Company as technical advisers in this project. The B.T.H. part, we are informed, is two-fold—to make an assessment of the hydro-electric potential of the area, and as electrical advisers to the development company. The work to be done by B.T.H. will be carried out concurrently with a mineralogic survey by the Lundberg Exploration Company and with a forestry survey which is being carried out by the Ranking Company of Montreal, in collaboration with the Hedlunds Travaru Company of Sweden. Most of the survey work will have to be done by aerial methods as there are no roads. The "power" area is some 470 miles long and varying in width from 50 to 150 miles, with an approximate total area of 50,000 square miles, and is probably the only area of British Columbia about which little or nothing is known. The survey, as a whole, has as one of its aims the establishment of a mono-rail track from near Fort McLeod to the Yukon border, which will allow cars to travel, above ground, at speeds up to 180 m.p.h. Altogether, about 5,000,000 dollars will be spent on preliminary surveys.

Exhibition of the Physical Society

No. I

THE forty-first Physical Society Exhibition, held in the Old and New Halls of the Royal Horticultural Society, was opened on Monday last by Professor P. M. S. Blackett, M.A., F.R.S., and continued until yesterday. We describe below a small number of the exhibits which were of engineering interest.

The Royal Aircraft Establishment, Farnborough, showed two exhibits, one a caesium clock in air-portable form, and the other an anti-vibration mounting with a stiffness effectively zero. The caesium clock differs from the laboratory instruments hitherto known in that it is not continuously pumped, but is evacuated and sealed. The life of the instrument is therefore finite, but is not expected to limit its use. No information is available as to the application of the instrument; it would seem that the accuracy is higher even than is needed for an inertial navigator, which, obtaining its results by double integration, demands very great precision. However, such a time source might render practical radio range-finding without any emission, original or reflected, from a vehicle by, in effect, measuring the time taken for a signal to arrive from a known point. One substantial advantage of a caesium clock for this application is that it can be started up from cold and will be running consistently within a short space of time, say, an hour. In addition, it is insentitive to its environment, being affected only by the ambient magnetic field.

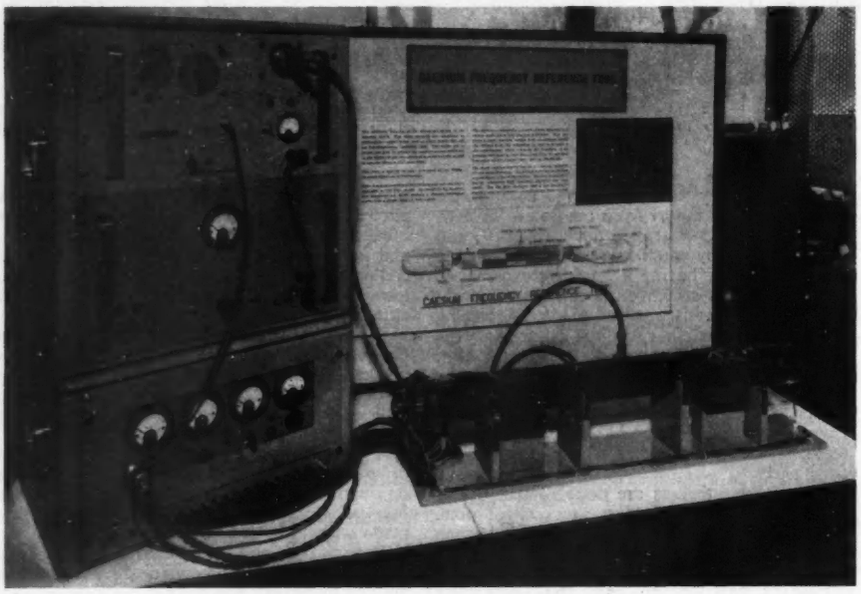


Fig. 1—Caesium frequency reference source using the 3-4 transition to establish frequency with a stability of 1 in 10^9

The theory of the instrument cannot be detailed here; suffice to say that the input of a signal of frequency 9192·63185 m/cs (this frequency is observed by comparison with quartz crystal clocks) effects a very large change in the rate of transition of caesium atoms passing through the chamber in the centre of the instrument. On the right in Fig. 1 can be seen the source, a quantity of caesium kept 10 deg. or 20 deg. above melting point by an electric heater. Vaporised caesium drifts into the copper tube leading to the central chamber, and a magnetic filter surrounding the tube diverts all atoms in the high energy state. In the corresponding tube at the far end a filter of the opposite polarity intercepts all atoms which have passed through unchanged; the atoms comprising the required signal are ionised upon an electrode, and the signal strength amplified by an electron multiplier.

A crystal-controlled oscillator generates a signal of 5·0068 k/cs, which is modulated by a multiplier of 1836 to provide the natural frequency of the clock. This signal is varied over a band width of about 40 c/s and the signal from the clock proper used to detect the exact frequency required; the oscillator is driven to locate this frequency in the centre of its output band. The accuracy expected in practice is of the order of 1 in 10^9; the instrument shown was built by Standard Telephone and Cable Company.

The anti-vibration mounting is intended to overcome the difficulty of insulating equipment from low-frequency excitation, which requires an elastic mounting to allow a very large deflection. The demonstration model, seen in Fig. 2, employs as the principal energy store a leaf spring connected to the load by a linkage which is allowed to pass " over centre "; as it does so it will, of course, have a negative rate. A second resilient member is provided in the form of a coil spring in tension; this is so arranged that its rate is equal and opposite to that of the leaf spring at its full deflection. This is demonstrated by a disproportionately large movement of the scale pan once the critical load has been reached. It is expected that this principle will have practical application to the weighing of articles which must come very close to a known weight; in effect, it will enable a spring balance to emulate a mass balance. An example of an anti-vibration mount designed for a static load of 50 lb is illustrated in Fig. 3; here both positive and negative rate media are coil springs. The mountings are adjustable by varying the initial compression of the central spring; the core must be constrained in rotation, since the surrounding cluster of springs is unstable.

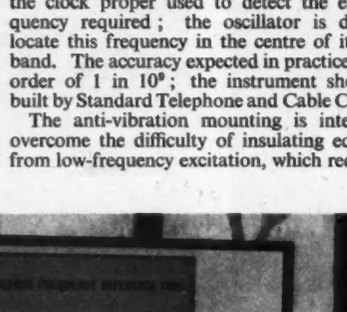


Fig. 2—Non-linear spring system applied to a balance

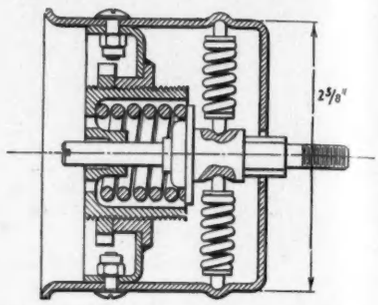


Fig. 3—Anti-vibration mounting of zero stiffness

An interesting example of the devices for measuring the thickness of a material from one side was the " Visigauge " of Dawe Instruments, Ltd., 99, Uxbridge Road, Ealing, W.5. This gives high accuracies on materials which are good conductors of ultrasonic frequencies, and lower accuracies on materials such as lead and plastics. It works by determining the natural frequency of vibration in the thickness direction, and hence is capable of working to lower thicknesses than " echo sounder " instruments; its range may be from 0·005in up to 2·5in, a single oscillator covering a frequency range of 2 : 1. The oscillator unit, which is shown in Fig. 4, has in its face a cathode-ray tube; the frequency at which the power consumption of the sample is large is denoted by a vertical line on the face, and the corresponding thickness can be read directly off a scale for the appropriate material. The governing parameter is the speed of sound in the material; this varies only as the square root of Young's Modulus and density, and the manufacturers believe that alloying, heat-treatment and degree of working can produce changes of the order of ½ to 1 per cent. The full accuracy of the instrument, which can be read to about 0·02 per cent, can be realised by making

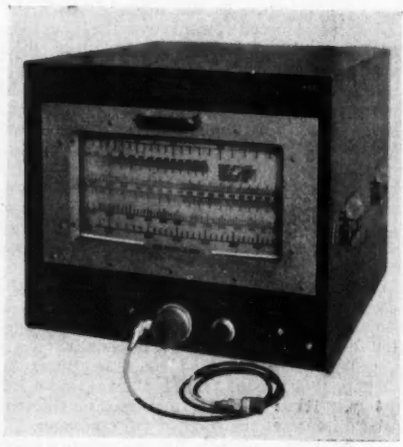


Fig. 4—The " Visigauge " indicates the natural frequency of vibration in the thickness direction, and can be calibrated to display thickness directly

samples of the appropriate material whose thickness is known. Drift of the oscillator can be countered by driving from it two transducers alternately, one applied to the standard and the other to the unknown.

The transducers are coupled to the set by coaxial cable, the length being dependent upon the frequency range in use ; for such applications as ship surveys, cable lengths may reach 1000ft. The transducers are of quartz or barium titanate, and for working on markedly curved surfaces must be specially shaped. The surface to which they are applied must be reasonably smooth and without a thick layer of paint or scale ; deposits on the opposite surface will be excluded from the measured thickness, but will affect the damping of the vibration. Where accuracies within 1 per cent are desired, the coupling between transducer and workpiece must be consistently maintained. Tight coupling, which shows thinner thickness readings, can be obtained by lubricating the surface with glycerine or water and rubbing the crystal on. Loose coupling can be secured by such methods as applying heavy grease, plastic tape, or a spacer around the crystal. For surveying flat plates, the transducer can be floated on a film of water, and for monitoring corrosion in plant one could be cemented permanently to the part concerned. The makers claim that the instrument is equal to assessing the increase in thickness of a part during metal plating. The " Visigauge " runs off 50-cycle a.c., weighs 140 lb, and has a scale 16in long ; that shown is graduated for second, third and fourth harmonics besides the fundamental.

Dawe Instruments, Ltd., also displayed a high-frequency stroboscope, which uses as its light source a Ferranti cathode-ray tube. The standard tube has a phosphor with a blue luminescence and the decay time is less than 3 microseconds ; an alternative tube of lower luminous efficiency has a decay time less than 1 microsecond. The light pulses are obtained by modulating the grid of the tube, so that duration and frequency can readily be controlled, and pulse rates up to several kilocycles are available.

In Fig. 5 is seen the general-purpose and

Fig. 5—The unusual McArthur microscope is portable and requires only fine focusing

research microscope shown by McArthur Microscopes, Ltd. Minute as the instrument is, the optical system is of conventional proportions, the light from the objectives being turned along the base of the instrument and then up into the eyepiece by prisms. The slides rest above the objective, and therefore are always at a fixed distance, so that focussing is largely automatic ; it can be seen that the fine focussing control is graduated in microns. Three objectives are mounted in line on a plate, and can be changed by a movement of the middle finger ; these are standard Cooke lenses except that their metal bases have been removed. The condenser is mounted above the slide, so that the object can be seen through it, which is an advantage for tiny objects, and there is a visible iris. A stainless steel mirror, folded flat in the illustration, provides illumination, but a self-contained electric illuminator, no larger than the top of the instrument, can replace it, and affords sufficient light for projection with the higher powers. By using partial reflectors, cinematograph or 35mm still photographs can be taken of the subject while it is observed through the eyepiece, and this apparatus does not prevent the instrument being portable. The construction of the microscope gives a high degree of immunity from arctic or tropical environments, the main components being light alloy with stainless steel fittings. Brass parts are satin chromed to A.I.D. specification, and springs are of beryllium copper. Mounting and sealing are by " Araldite," and the black finish inside the light tube includes a fungicide. Very little lubricant is required for the few moving parts, and it is provided by silicone jelly unaffected by extremes of temperature. It is reported that the instrument has been used in dug-out canoes in Africa, on Mount Everest, and even in the London " Underground."

A. Gallenkamp and Co., Ltd., Sun Street, E.C.2, displayed the prototype of a bomb calorimeter, with a heated water jacket that provides adiabatic conditions—no gain or loss of heat from the calorimeter to its surroundings. This eliminates time-consuming corrections and, experiments suggest, will allow heats of combustion to be more accurately determined. The water jacket has a minimum thickness of 1in and includes the lid ; the water is circulated by a pump and into it there dips a thermistor. Another thermistor is immersed in the calorimeter, and the two are connected in a bridge circuit. Any out-of-balance due to the calorimeter being hotter than the jacket brings into action the jacket heaters, which are of low heat capacity to give minimum time lag. The control system has been found capable of holding the temperature difference down to 0·1 deg. Cent. when the calorimeter temperature is rising 3 deg. Cent. per minute. There is in the jacket a cooling water coil to return the temperature to the usual 23 deg. Cent. initial value.

In Fig. 6 is shown a torsional vibration pick-up on the stand of Southern Instruments, Ltd., Frimley Road, Camberley, Surrey. The siesmic mass running within this is driven not by viscous or spring forces, but by eddy current drag ; it is magnetised and surrounded by a copper cylinder which runs at crankshaft speed. The natural frequency is likely to be outside any desired working range, since it is 5 c/s. The inertial rotor runs on ball bearings, and carries two probes which change the inductance of coils carried in the casing as the mass moves through its spring-restrained travel of 4 deg. These inductances are connected to a coil on the front of and coaxial with the casing. The coupling unit, which does not rotate, carries another coil surrounding this one, and the makers' frequency-modulation amplifier system allows the change in inductance of the rotating coil to be instantaneously traced. The output signal is directly proportional to the amplitude of the oscillation of the seismic mass, having a sensitivity of about 2·5V per degree. The device can be calibrated when at rest by means of the fixture seen in the illustration, which imposes an accurately known displacement upon the rotor ; it is not necessary to remove the device from the engine. The instrument is practically insensitive to all translational oscillations.

The Siemens-Ediswan Research Laboratories, Woolwich, demonstrated a translator, intended for telephone applications, using a magnetic drum as an information store. In some telephone areas, such as the London Directory area, it is necessary to route calls by means of decimal digits which differ from the exchange codes dialled by subscribers. This is because only one code is used to identify an exchange in the directory, whereas calls originating in diverse places have to take different routes to reach the called exchange. The need for performing such translations will increase when subscribers are enabled to dial trunk calls.

The digits dialled by the subscriber are received by a register which makes use of a translator to change the digits received by the register into

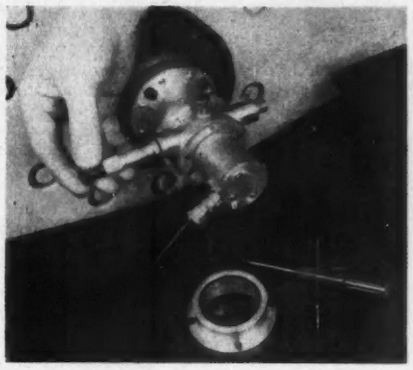


Fig. 6—Static calibration of a torsional vibration pick-up

those to be sent out for setting up the telephone connection. If the translator is rapid in operation it can be shared by several registers : a single electronic translator can thus serve all the registers in a busy telephone exchange.

The information is recorded in binary code as small magnetised areas on the magnetic oxide-coated surface of the drum, which rotates rapidly and so induces e.m.f.'s in pick-up heads. In a machine operating in the parallel mode, which translates three-digit exchange codes, three tracks on the drum are selected by means of the dialled code digits. When the pick-up heads of all three tracks give coincident output pulses, gate-circuits are opened which allow the information stored to pass back to the register.

The translator uses junction transistors for all its amplifier and trigger circuits and these circuits are constructed in the form of small plug-in units. Selection of the required heads on the drum is carried out by using saturable magnetic cores as switches. Changes in the translations can be made by rewriting information on the drum at the appropriate address positions. This information can be prepared by telephone administrations in the form of punched tape or cards.

For the purpose of demonstration, the machine has been programmed to play the game of noughts and crosses. This is carried out as follows :

There are 1000 digit positions on each track round the circumference of the drum. On each of ten tracks, single groups of 100 digit positions are recorded, the group on each track being staggered with relation to the group on each other track so that the selection of any single vertical time slot on the drum will cause a pulse to be read out from the reading head on only one track. These pulse groups correspond to each of the nine separate locations in the noughts and crosses square, one group not being used.

In addition there are twenty-seven other tracks, each corresponding to either a X, a O or a blank in any one of the nine possible positions. On these tracks are recorded over 700 possible arrangements of X's and O's in the grid.

When any particular stage in the game has been reached and it is the machine's turn to play, a particular arrangement of X's, O's and blanks is being stored on nine three-state stable staticisors, controlling saturable magnetic cores. These staticisors receive pulses from the reading heads on the twenty-seven tracks. Corresponding to this particular arrangement, pulses have been recorded on a particular time slot on the drum, such that, when this time slot appears under the reading heads, pulses are obtained which cause all nine staticisors to give an output. The output of each staticisor is fed to a coincidence-of-nine gate, which only gives an output when it receives simultaneously an input pulse from all nine staticisors. The time slot at which this output occurs has been chosen so that it occurs during the group on the particular one of the nine tracks which corresponds with the position in the noughts and crosses square into which the correct answering move has to be made. The effect of an output pulse being obtained at this time is to place a X into the correct square. This is achieved by turning on a transistor to light a lamp in the required position on the display unit.

(To be continued)

Modifications in a Precast Concrete Works

SEVERAL recent articles in this journal have drawn attention to contemporary trends in the use of precast concrete for structural work. It is not simply a case of increased usage, but of a trend to larger sizes, and more complicated shapes. This has led to modifications of manufacturing methods in the precast concrete industry; we were recently able to see one example of this kind at the works of the Modular Concrete Company, at Bedfont, Middlesex.

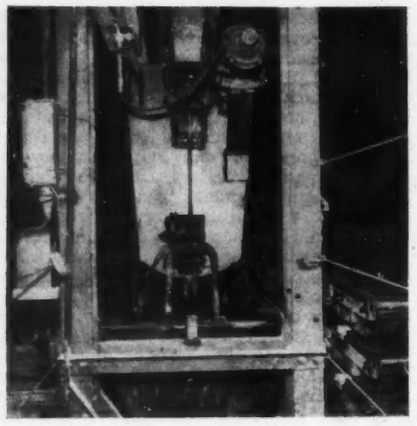
The works was laid out for the production of—by present standards—small precast units, such as have been used, for instance, in a system of prefabricated house construction. A concrete batching and mixing tower stands at one side of the main production building, and supplies concrete: (*a*) into dumpers for work in progress in the open yard; (*b*) into a rail-mounted overhead skip, which can traverse across the factory floor, to deposit concrete at any of several working stations. In the original layout of the factory, each of these stations comprised a vibrating table, with roller conveyors, extending along the length of the factory building, leading to it. Moulds were thus rolled into position, filled and compacted, and then rolled away to a curing area. Two such stations are still in operation, but the larger components now being cast are often too

Travelling skip at loading point

heavy or too cumbersome to be moved on the roller conveyors. So the following method of concreting is used for these larger components.

A double row of stanchions runs longitudinally down the centre of the building. The "dead space" between them has been utilised by constructing a track for a concrete skip which is operated, largely, automatically, from the batching station in the tower, there being an intercommunication system between the casting area and the batching tower. The casting area for the heavy components is in one bay of the works, which is served by a 3-ton e.o.t. crane. The crane capacity is the limiting factor in the size of component which can be cast; the more complicated shapes include, for instance, a flight of stairs with a landing at the top and the bottom, all cast in one piece.

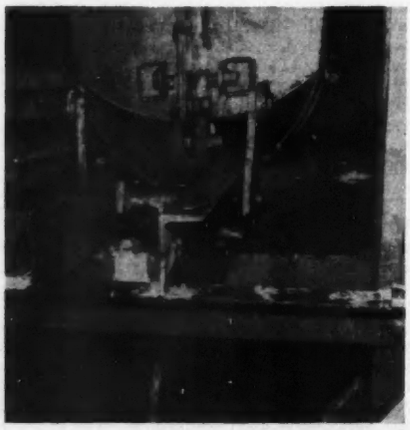
Our first illustration shows the loading station for the newly-installed travelling skip. Concrete is dumped into it from the skip serving the vibrating tables, as described above. The illustration shows the bottom-opening doors and electric motor drive of the travelling skip, which carries the full batch from the 14/10 pan concrete mixer of the batching plant. The batching station operator starts the skip on its run on receiving instructions from the casting floor, and at the same time sets a trip, for stopping and emptying the skip, at the required delivery point. This trip—a U-shaped bar—is shown in its raised position and engaged with the catch for opening the skip doors, in the second illustration. The travelling skip, as may be observed, discharges into another skip below it, which can be moved by the crane, as required, for the actual casting operation. On its return run, the travelling skip passes over two converging rails shaped



Skip at delivery point, showing, in its raised position, the U-shaped bar, which stops the skip and releases the doors

like a Y, as shown in the third illustration. These rails draw the doors of the skip together until they are nearly closed. As it travels on, the skip strikes and depresses the two cranked levers shown in the foreground of the illustration, thus raising their lower arms (one of the lower arms is shown on the left) which engage against the doors of the skip and fully close them.

The skip run is at present being extended beyond the end of the casting shop to serve an open-air casting yard. Here advantage is being taken of unrestricted area to give a layout with the most advantageous mechanical handling. Shuttering is also to be simplified. A set of steel channels has been cast, accurately level, on concrete plinths. Slots have been cut at 6in centres in the top flange of each channel, and steel "soldiers" can be fitted rigidly into any of these slots, thus giving a system of shuttering supports sufficiently flexible to meet most of the shapes needed without the use of large timbers. A further stage of mechanical handling is envisaged for light units, for which a stillage system of handling is to be developed. An increase in production of about 10 per cent is claimed for the skip installation as it is now used in the casting shop.

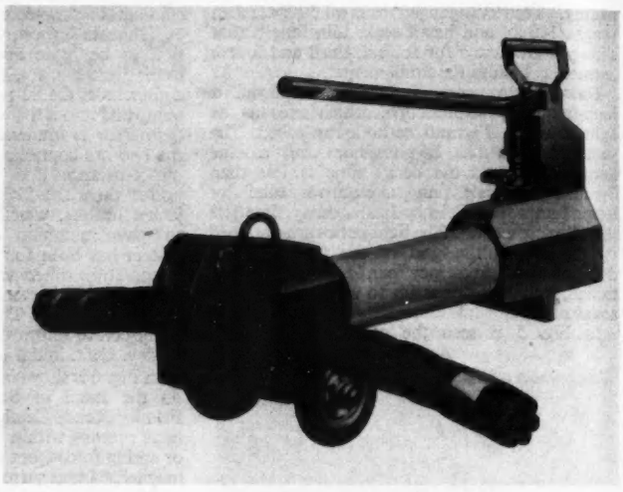


Door-closing mechanism. The skip is travelling towards the camera. The doors are partially closed by the converging guides, and finally closed by the lower arms of the cranked levers

Portable Hydraulic Shear for Rods and Cables

A PORTABLE hydraulically-operated shearing machine for rods, wire ropes, cables or chains, has been developed by the Copelaw Engineering Company, Ltd., Mowden Hall, Darlington, and is made in five sizes covering diameters from ⅜in to 2in, or in the case of electric cables 3½in. One of the heavier models for cutting 2in diameter cables is illustrated below, and it is this model which can be adapted for shearing electric cables up to 3½in diameter. It has a gross weight of just under 300 lb, and is provided with wheels at the shearing head end to facilitate manœuvring on site.

In these "Carricut" machines, as they are known, shearing power is provided by a handle-operated, double-acting pump built into the oil reservoir at one end of the machine. The piston of the hydraulic cylinder connecting the pump assembly to the shearing head carries a concave chisel-form punch. This punch is guided in the head over its full working stroke. When a valve in the pump assembly is opened at the end of a shearing stroke, the piston, together with the punch, is retracted back into the cylinder by the action of a return spring. During the shearing stroke the cable is fully supported by an anvil



Portable hydraulic shearing machine for wire ropes up to 2in diameter or electric cables up to 3½in diameter

block on the head. This anvil block is pivoted on the lower side of the head so that it can be swung down for the entry of the cable. When the cable is in position the block is swung up and locked against the shearing pressure by a pivoted latch at its top, which registers behind two pads on the front of the head.

For certain applications, the machine is made with a separate foot-operated pump assembly which is connected to the cylinder and shearing head by hydraulic cables.

Technical Report

The Hydrogen Engine. The Oxidation, Decomposition, Ignition and Detonation of Fuel Vapours and Gases, No. XXVII. By R. O. King and Mogens Rand. Defence Research Board of Canada.—Experiments made with hydrogen as the fuel for an Otto cycle engine show that optimum performance in terms of power and economy is limited only by pre-ignition arising from the temperatures attained by the ceramic core of the spark plug or by the exhaust valve, or from nuclei formed by pyrolysis of lubricating oil vapour. On reduction of the magnitude of these igniting effects it became possible to operate the engine with speeds rising to 1800 r.p.m. and the compression ratio fixed at 12 : 1. A value of 146 lb per square inch for I.M.E.P. with an indicated thermal efficiency of 37 per cent was obtained when the maximum power mixture strength was used. A value of 90 lb per square inch was obtained for I.M.E.P. with an indicated thermal efficiency of 47 per cent with a mixture of 55 per cent weak. These values exceed, by a wide margin, any recorded in the literature of the subject.

Prospects of the Motor-Cycle

ON Thursday, March 21, the Automobile Division of the Institution of Mechanical Engineers discussed the relative utility of motor-cycles and light cars for transport. The chairman was Mr. R. A. Wilson Jones, and the discussion was opened by Mr. Alan Baker. In his address he pointed out that this country was characterised by high traffic density, a predominance of short journeys, good road surfaces and an absence of extremely long climbs or descents. A vehicle for utilitarian transport required manœuvrability, ease of parking, weather protection, road-holding rather than comfort, and accommodation for luggage and more than one person. "Scooters" generally fell short of full weather protection; they were, however, "socially acceptable" to a greater degree than motor-cycles, and the number of garages prepared to offer service was increasing. He displayed a slide of a Maico "Mobil" as an example of an advanced scooter with a conventional motor-cycle configuration, a body that enclosed the front wheel and included a wind-screen, and luggage stowage. The classical motor-cycle was tending to become a utilitanin vehicle; the extreme in this trend was the "LE" Velocette, which was refined, extremely silent and provided with leg shields. He pointed out that this machine was cheaper than scooters with similar sized engines, as was the general rule.

One possible development of the motor-cycle was demonstrated by an experiment sponsored by *The Motor Cycle*, a Royal Enfield with a streamlined shell of glass-reinforced plastic (illustrated). The comfort of the rider was surprisingly good, the performance of the machine benefited, and the fuel consumption was lessened by 25 per cent even at 30 m.p.h., and by 35 per cent at 60 m.p.h. While a shell as an accessory necessarily added to the weight and cost of the machine, that need not be the case if it was original equipment. A streamlined motor-cycle with a twin-cylinder, two-stroke engine, would meet every requirement for a general-purpose vehicle, except that it would not have an open frame.

The motor-cycle combination, he pointed out, while the most manœuvrable of vehicles, was exacting in driving technique. Three-wheeled vehicles had changed their character entirely; having previously been built for performance high almost to motor-cycle standards, they were now of very low performance. The four-wheeled vehicle was adversely affected by heavier registration and purchase taxes, but its basic cost was also higher, due to a disproportionate increase in mechanical complication, and to the relatively small volume of production.

The discussion which followed was of an informal nature; we give below the views of various contributors in separate paragraphs.

The streamlined "solo" was an attractive proposition. The great advantage of the motor-cycle was its low price, and the disadvantage was the need for special clothing. Even a car of less than 600 c.c. was vastly more expensive.

This country, while a major exporter of motor-cycles, was importing scooters; since scooters were a particularly expensive vehicle, it was obvious that the indigenous motor-cycles were not adequate. The manufacturers must progress to a product to meet modern demands.

The only real advantage of the scooter is the ability to ride it wearing a long coat or a skirt, and for this the purchaser is prepared to pay.

Streamlining need not make a motor-cycle more expensive, and even the rider who put performance above all else would choose it. The experimental R.E. was praiseworthy and a similar machine with luggage-carrying capacity would compete with a car. The lack of such machines showed that the industry was lethargic, for years they had turned out products of which the contributor was sick of reading. It should be realised that machines such as this, or larger versions of the present scooters, were bound to come. Austerity motor-cycles were not in demand; it was noticeable that scooters usually carried a host of optional extras.

The customers' reaction at the recent show at Amsterdam was not prejudiced against British machines, but it was not considered wise or practical to buy them. The frame design and styling were inferior to Continental standards, whose detail design and chrome plating were also superior, but the British machines were more costly. Our experience of motor-cycle manufacture should allow us to build extremely advanced machines resembling the R.E.; there would be a saving in cost due to there being less need to finish enclosed components.

In considering the project of an enclosed motor-cycle a limitation was the need to halt, and here a third wheel was the answer. On the Continent the three-wheeler had established itself at the expense of the motor-cycle, and there was a large potential demand for such a vehicle in this country. However, engines larger than those of motor-cycles were essential to give sufficient safety and performance.

The tendency for the lowest incomes to rise would lead to an increased demand for three-wheelers and light cars, but the problem of garaging the vehicle at night would always favour the motor-cycle. The motor-cycle could not be rivalled for rapid travel on busy roads, nor could any other vehicle provide fast, long-distance touring cheaply. Enclosure, therefore, must come; it need not add greatly to the cost since, for instance, there would no longer be any need for expensively finished petrol tanks.

Enclosed solo motor-cycle: the shell is in two main parts, front and rear, and is made of glass-reinforced resin. There are two fixed headlights in the nose, and cooling air is directed to the engine from in front of the rider's feet. The position of the windscreen is adjustable

The motor-cycle was distinguished, at present, by the excellence of its construction; this feature must not be abandoned. The superior handling qualities and response to the controls would unfailingly attract the users of scooters. Deficient on present motor-cycles was the ability to make traffic signals at night; motor-cycles, like commercial vehicles, had eschewed the vulnerable and unreliable semaphore indicators, but they should be fitted with flashing indicators.

The purchaser of a scooter wants transport, and not pleasure, from it; motor-cyclists were a different class of customer. The future would be dominated by traffic congestion, and the three and four-wheeled light vehicles known at present would disappear because they were not fast enough; a certain minimum performance would be demanded in future.

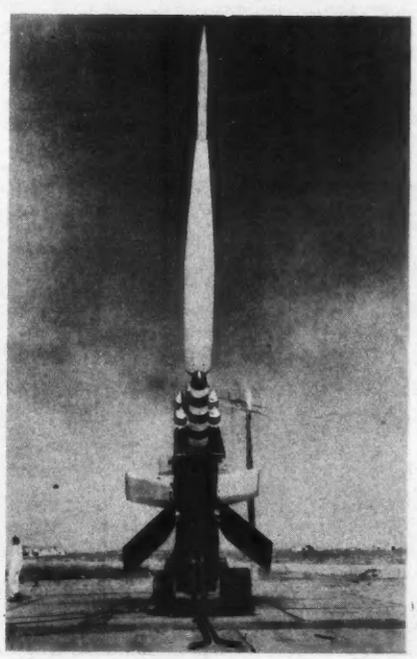
The chairman, summing up, pointed out the enigma that there appeared to be a demand for miniature cars, and yet no major manufacturer in this country would build them. The motor-cycle and the light car, he felt, were not directly comparable; the satisfaction afforded by a motor-cycle was vastly greater. It was probable that streamlining would be accepted for motor-cycles, although the experimental R.E. might be too advanced for the public at present. On the research machine the tail had been kept short for the sake of stability, but luggage space could well be provided.

Recoverable Test Vehicle

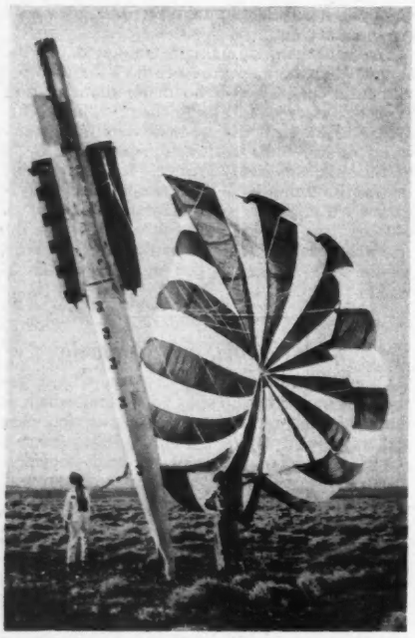
OUR illustrations show a test vehicle for ram-jets and other missile equipment which is intended to survive the return to earth. The vehicle, the Bristol "Bobbin," falls under a parachute: the energy of its final impact is dissipated in driving a steel spike into the ground. Although the vehicle might suffer some damage, as in the example illustrated, the "Thor" ram-jet engines remained intact. Noteworthy in the illustrations are the large fins mounted on the four boosters, presumably as a safeguard against uneven burning, and the use of only two fins on the vehicle proper, able to counteract uneven thrust. Films taken of "Thor" engines in flight have shown that they were flown on vehicles which were not roll stabilised, although these vehicles were said to be shattered in flight by explosive charges in order that the parts containing instruments should fall relatively gently to earth.

Tests to design and manufacture the long nose-spike were carried out by using a dummy vehicle which was dropped vertically from a crane, hitting the ground at the correct velocity. Decelerometers and high-speed cameras measured the rate of impact deceleration. To find out how the nose spike would react to various types of terrain, half-scale models of the test vehicle were dropped from a "Sycamore" helicopter at various places over the Woomera guided weapon range in South Australia.

Parachutes for "Bobbin" were developed by the British Irvin and the G.Q. Companies. For deceleration tests, a full weight dummy test vehicle was dropped from a "Canberra" aircraft at very high altitude over Salisbury Plain. The dummy accelerated in free fall to well above Mach 1, and six ribbon parachutes were deployed by a time switch. After initial deceleration the



The "Bobbin" before launching, showing the steel nose spike



"Bobbin" with spike embedded in earth: notice the missing gore to give stability to the canopy

small parachutes were released by an explosive charge and, in falling away, drew out the main canopy, which was a nylon parachute 30ft in diameter. In practice, the large canopy slowed "Bobbin" down sufficiently to absorb the shock of the actual touch-down. The vehicle was then recovered and not only was data about its performance gained from instruments mounted inside it, but the test vehicle could also be carted back to the firing base and used again.

"Bobbin," which was produced by Bristols under the Ministry of Supply research programme, has contributed substantially to the development of a surface-to-air missile on which the company is at present engaged.

Two Fire-Fighting Tenders

We illustrate below two interesting new fire-fighting vehicles, a foam tender and an aircraft crash tender, which have recently been built by Merryweather and Sons, Ltd., Greenwich High Road, London, S.E.10. The foam tender with an auxiliary trailer pump has been supplied to the London and Thames Haven Oil Wharves, Ltd., and is primarily intended to convey foam compound and hose lines to any part of the wharf area to link up with the hydrant system. It will provide a source of foam compound and water mixed in correct proportions ready for feeding to either foam generating fixings, on the storage tanks or incorporated in portable foam towers, or to hand-operated foam branch pipes. The tender is of the firm's "Marquis" design, with a 120 b.h.p. A.E.C. diesel engine, which is suitable for pumping continuously over long periods.

The tender carries a 500-gallon foam compound tank, and a special foam pump driven by an auxiliary power take-off enables the compound to be pumped to a 180ft hose reel from the tank or from drums. Under certain conditions where the auxiliary trailer pump is called into service it can be fed with foam compound pumped through the hose reel. The appliance can provide about 700 gallons per minute of water and foam solution which, in conjunction with appropriate foam generating equipment, can produce about 5000 gallons of foam a minute. Two sizes of branch pipe are carried, one producing 1600 and the other 800 gallons of foam per minute.

The main turbine pump of the tender is capable of delivering 500/800 gallons per minute of water, and separate outlets are provided so that, if required, only water is discharged. Locker accommodation is provided on the vehicle for 2000ft of canvas hose, and it also carries a two-section light alloy extension ladder and two 42ft foam towers.

The airfield crash tender has been built for the Trinidad and Tobago Fire Service for stationing at Piarco. It is built on a Bedford four-wheel-drive chassis with a 110 b.h.p. petrol engine. The single-stage, main fire pump at the rear of the tender delivers 450 g.p.m. at a pressure of 160 lb per sqauare inch or 550 g.p.m. at 120 lb per square inch. Equipment is provided for delivering foam, carbon dioxide, water and high pressure fog on to burning aircraft, all at the same time or singly or in any required combination. To enable the machine to drive close to a fire, equipment is provided to project forwards a heavy screen of water-fog, and carbon dioxide through nozzles and projectors situated beneath the front bumper. Controls for this front projector are situated in the cab.

A powerful roof-mounted foam monitor is operated by a fireman standing inside the cab with his head and shoulders through a hatch. Two hand-held roof-mounted fog nozzles work from the main high pressure pump and can be used to supplement the front-mounted nozzles. Two foam lines and a high pressure fog line can be used by firemen on the flanks of the vehicle. The foam lines and branch pipes are housed in lockers on each side of the vehicle with 75ft of canvas hose permanently connected to a foam outlet. The high pressure fog gun is linked to a reel carrying 180ft of rubber hose. Two 40 lb gas cylinders for the carbon dioxide equipment are mounted on each side of the tender which is also provided with a 250 gallon water tank and a foam compound tank.

Engineering Education Developments

Details were announced last week of a new project which has been formulated by Vickers Ltd. to assist technical education in this country. The company is making a grant of £150,000 for the building and furnishing of a hall of residence, for about seventy students, at the Imperial College of Science and Technology, London. In addition, it is establishing three engineering scholarships, each valued at £400 a year, at Cambridge University.

The hall of residence is to be built in Princes Gardens, South Kensington, near to the main buildings of Imperial College. It will be maintained and operated by the College, and of the seventy students which it will accommodate, up to fifteen are to be undergraduate apprentices from the Vickers group of companies. The hall will be available, by arrangement with the College, for the Vickers group, during vacations, as a staff college for management courses and other forms of education and training. It is hoped that the hall will be ready for occupation by 1959; at the suggestion of the Imperial College, the building will be known as Weeks Hall, to signalise the active part taken by Lord Weeks, until recently chairman of Vickers Ltd., in formulating the scheme.

The scholarships at Cambridge, to be known as Vickers scholarships, will be tenable for three years. Initially, they will be introduced at yearly intervals, namely, this year at Christ's College, in 1958 at Downing College, and in 1959 at Trinity Hall. Applicants for the scholarships must, of course, possess the necessary entrance qualifications for the University; selection will be based on the General Certificate of Education examination at scholarship level and a personal interview before a selection board at the college. Candidates will be expected to indicate their intention of pursuing a career in one of the branches of engineering practised by a company of the Vickers group. Each holder of a scholarship will normally be required to enter as an undergraduate apprentice in one of the companies in the group having an established apprentice training scheme. After serving one year as an apprentice, he will take up residence at Cambridge and then finish his apprenticeship by a further year of training with the company. The scholarships at Cambridge, it should be noted, are additional to those already offered by the company, making twenty named scholarships of various kinds.

These developments in the Vickers Ltd. schemes for technical education result from the work of a committee set up within the group in 1955 by Lord Weeks. That committee, under the chairmanship of Mr. H. H. Gardner, was directed to consider the problems raised by the shortage of technologists and to formulate a unified group educational scheme. Last week, a brief review of the scheme was given by Viscount Knollys, chairman of Vickers Ltd. He

(Left). Fire-fighting foam tender for service on Thames Haven oil wharves. This vehicle can deliver about 5000 gallons of foam a minute. (Right). The airfield crash tender for British West Indies is equipped to deliver foam, carbon dioxide, water and high pressure water-fog, singly or in any combination

said that it included apprentice schools with hostels generally attached to them; management training courses, and university scholarships and sandwich course awards to apprentices, for which the group, in co-operation with local education authorities, accepted financial responsibility. The group had appointed an education and training officer to co-ordinate the work in the scheme. Lord Knollys stated that there were now over 5000 apprentices in the Vickers group, and that they were given every opportunity to qualify for the existing scholarships and to equip themselves not just in one branch of light or heavy engineering, but, if their talents lay that way, in such directions as aeronautics, electronics and nuclear energy. The basic policy of the scheme, he added, was that boys would be helped through engineering and student apprenticeship, and through undergraduate apprenticeship, to reach the highest possible academic standard consistent with their mental calibre.

H.M. Submarine "Explorer"

LAST week the experimental high-speed submarine, H.M.S. "Explorer," arrived for a short stay in the West India Dock and by courtesy of the Admiralty we were able to pay a brief visit to the ship. The "Explorer," which has a length overall of 225ft 6½in and a breadth of 15ft 8in, was built at Barrow by Vickers-Armstrongs, Ltd., to Admiralty designs and was accepted into service on May 8 last year. This submarine has a standard displacement of about 780 tons and a submerged displacement of approximately 1000 tons, and is of streamlined form to enable a high under-water speed to be attained. No armament is carried; the main propelling machinery consists of turbines driving through double reduction gearing and supplied with steam and carbon dioxide produced by burning diesel oil in an atmosphere of steam and oxygen produced by the decomposition of high-test peroxide (H.T.P.). Apart from providing the opportunity for personnel to gain experience in the operation of this particular cycle and the handling of a submarine at high speed under water, the ship is serving as a target to train surface forces in the tactical measures necessary to combat high-speed under-water craft. Experience in service has demonstrated that the manœuvrability of the ship at high speed submerged is good and that the ship is readily controlled at all speeds. While the high speed attained is not apparent to the crew except as indicated by instruments, the submerged speed attained is in excess of 20 knots.

The "Explorer" is propelled by twin screws, which are driven by conventional means on the surface and when submerged, except that additional power is available when submerged from two sets of H.T.P. "spurt" machinery. Each set consists of a double reduction geared turbine which, when it has reached synchronous speed, can be clutched to the main shaft to give the submarine high under-water speed, a triple pump, a proportioning device, a three-cam control valve, catalyst chambers, a combustion chamber, a condenser and compressor. All the machinery, which is installed in compartments which are closed when it is in operation, is under remote control.

The H.T.P. is carried externally to the main hull and, together with the diesel fuel oil and feed water, is handled by a triple pump which incorporates its own lubricating oil pump, cooler and filter. Power is provided by a 150 h.p. motor which drives, through a gear wheel, three pinions each driving its own impeller. All three liquids are delivered through a proportioning device to a control valve. The former consists of four meters to pass and control the correct proportions of the fuels as required by the load and as controlled by the load valve which is in the H.T.P. line to the catalyst chamber. Three of the meters deal with the H.T.P., oil fuel and water respectively, while the fourth allows sea-water to enter the submarine to compensate for the loss of weight due to the consumption of fuel.

Operation of the "three cam" control valve, after the preliminary preparations have been made and the condensate and triple pumps are running, starts the plant. In the "off" position, to which the valve is set during the stand-by period, all three fuels are recirculated to the suctions through by-passes. However, the first movement of the valve allows H.T.P. to pass through the load valve to the lagged twin catalyst chambers, where decomposition of the H.T.P. occurs. The resulting steam-oxygen mixture passes to the combustion chamber where there is an igniter which is energised by a switch which admits oil to the igniter sprays. When ignition has been initiated the second and third movements of the three-cam valve are made to pass water and then oil fuel into the combustion chamber. The purpose of admitting water is to cool the combustion chamber and to reduce the gas outlet temperature to that required at the turbine inlet. The products of combustion pass to the turbine through a changeover valve, but during the starting-up period this valve discharges the steam-oxygen mixture overboard to avoid build-up of neat oxygen in the condenser. The low pressure condenser is designed to condense the steam and separate the carbon dioxide, the former being returned to the feed tank by condensate pumps, while the latter is discharged overboard by two Lysholm compressors working in series.

The steam-gas mixture, containing 14 per cent by weight of carbon dioxide, enters the turbine at a temperature of about 1000 deg. Fah., and a pressure of 526 lb per square inch at full load, and leaves at about 200 deg. Fah. To meet the operational requirements for quick starting, large clearances were necessary, so that an impulse turbine was chosen. At admission the turbine has a velocity-compounded impulse stage followed by five pressure-compounded stages. A carbon ring gland seal prevents steam and carbon dioxide escaping into the turbine room, while the jointing of the H.T.P. lines, which are of stainless steel, is hard P.V.C. About 1½ tons of diesel oil fuel, which must be sulphur free in order to avoid the formation of sulphuric acid, are used to every 15 tons of H.T.P. The submarine is generally submerged to a depth of about, at least, 90ft before the "spurt" machinery is brought into operation and it is of interest to note that the gas discharged overboard leaves no trace on the surface.

"NERO" Experimental Low-Energy Reactor

A NEW experimental low-energy reactor has started operating on an experimental programme at the U.K. Atomic Energy Research Establishment, Harwell. It is known as "NERO," a name derived from the initial letter of the chemical symbol for sodium, and of the words "experimental reactor"; the final "O" indicates that it is a zero energy reactor. "NERO" consists of a graphite stack which can be varied in size up to a cylinder of about 14ft diameter by 10ft high within a concrete biological shield 2ft thick. Fuel elements of various kinds can be arranged within the graphite stack in any one of a number of possible lattice patterns. The restacking of the graphite to permit a change in the fuel element arrangement can be done in a few days. The reactor is controlled by two vertical cadmium control rods which can be moved into the graphite stack through the top of the biological shield. Cadmium "shut off" or "safety rods" are arranged to move into the graphite stack in a similar manner. The maximum thermal neutron flux is about 10^8 neutrons per square centimetre per second and the heat output is restricted to less than 100W.

The reactor will be used to investigate the physics design problems associated with the more advanced graphite moderated power reactors now under study by the Authority.

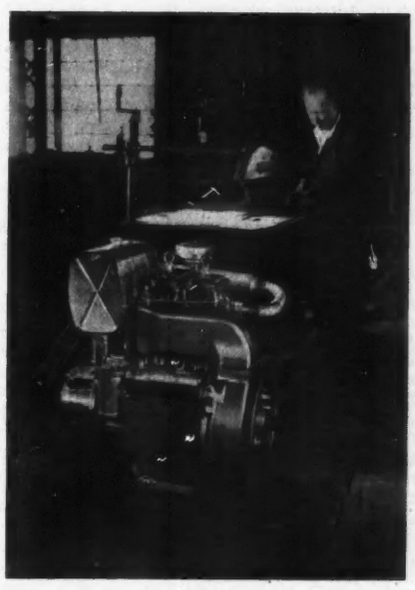
At first it will be used to check calculations on the effect of separating the fissile content of the fuel (e.g. U.235 or Pu239) from the fertile content (e.g. U.238): information of this kind is of great importance for the design of reactors in which nuclear fuel (e.g. plutonium) may be recycled through the reactor. Another application of the reactor is to investigate problems associated with the design study of a sodium cooled graphite moderated reactor.

"NERO" was designed and built by the Atomic Energy Research Establishment in association with the following industrial firms: Saben, Hart and Partners, Ltd., London; Technical Design and Tool Company, Ltd., Reading, detail design work; March, Ltd., Reading, steelwork fabrication; Royal Ordnance Factory, Nottingham, roof trolleys; H. M. Hobson, Ltd., Wolverhampton, control mechanisms.

Air-Cooled Oil Engine

AIR-COOLED versions of the "YB" series of diesel engines have now been introduced by Ruston and Hornsby, Ltd., Lincoln; single and twin-cylinder versions are designated "1 YBA" and "2 YBA." Cylinder heads and barrels are, like the crankcase, cast in iron. Cooling is by a fan attached directly to the flywheel; the power can be taken off at this or the opposite end of the crankshaft, or at half speed from the timing end of the flywheel. A starting handle is normally fitted at that end of the camshaft, and a decompressor is provided. Either direction of rotation is available, but clockwise on flywheel and hand crank is standard.

The twelve-hour ratings are the same as for the water-cooled engines up to 1250 r.p.m., at which the power is 5 b.h.p. per cylinder, but are ‡ h.p. lower, presumably due to the fan, at 1500 and 1800 r.p.m., the maximum power being 6¼ b.h.p. per cylinder. At intermittent rating a b.m.e.p. of 45 lb per square inch is attained between 1000 and 1100 r.p.m.



Air-cooled twin-cylinder diesel engine undergoing service trials

These are the first air-cooled engines produced by this manufacturer, and over 8000 hours' running under field conditions has been carried out with engines installed in dumpers, compactors and other contractors' plant. They carry the eighteen months' guarantee of "YB" engines, and run on distillate fuel, not blended with residual oil, to B.S. 209 (1947), Class A.

PORTABLE COLD STORAGE ROOM.—A lightweight portable cold room, which can be erected anywhere, has been designed by Messrs. Penfold and Partners, of 120–122, Victoria Street, London, S.W.1. It is constructed of completely insulated aluminium sections measuring 7ft by 7ft and weighing 85 lb, and incorporating holes and slots for assembly using special screws. A hermetically-sealed fractional horsepower compressor unit, using less than 1 unit of electricity per hour, is fitted externally and preset to maintain the temperature required. Models for zero and sub-zero temperatures are available and both humidity control and defrosting can be fitted.

Industrial and Labour Notes

Shipbuilding and Engineering Wage Dispute

The Minister of Labour, Mr. Iain Macleod, announced on Monday evening that he proposed to appoint a court of inquiry to examine the wage dispute in the shipbuilding industry. This followed the failure to reach agreement at renewed discussions between the Shipbuilding Employers' Federation and the Confederation of Shipbuilding and Engineering Unions. The Ministry's conciliation officers were successful in bringing about a resumption of negotiations, and both sides were ready to include consideration of such matters as productivity and restrictive practices in the conversations. At these talks, on Monday, the shipbuilding employers offered an increase of 8s. 6d. in the skilled men's basic weekly rate, and 7s. 6d. for unskilled men. The offer—approximately 5 per cent—was rejected by the union representatives, who, it is reported, were not willing to accept less than a 7½ per cent increase. As we go to press, conversations between the Ministry of Labour and the employers' and union representatives are still going on, but the shipyard strike, which started on March 16, has not yet been called off. Nevertheless, both sides have indicated their willingness to co-operate in the deliberations of the court of inquiry.

In the engineering industry, strike action in various selected areas of the country was started last Saturday. Again, conversations between the Engineering and Allied Employers' National Federation and the Minister of Labour are in progress. Reports at the time of printing indicate that the unions would be prepared to agree to an immediate 5 per cent wage increase without any conditions as to future claims being imposed at present.

Railway Wages

The Railway Staff National Tribunal last week announced its decision concerning the claim, originally submitted last October by the National Union of Railwaymen, for a 10 per cent increase in the rates of pay of salaried and conciliation staff employed on British Railways. It will be recalled that, last December, the British Transport Commission offered an increase of 3 per cent. That offer, however, was not acceptable to the N.U.R., as was an "improved offer" made in January. Towards the end of January, the N.U.R. asked that the 10 per cent claim should be referred to the Railway Staff National Tribunal. Sir John Forster, Q.C., acted as chairman of the tribunal, the other members being Mr. A. J. Espley, selected by the British Transport Commission, and Mr. E. Hall, who was selected by the N.U.R.

The tribunal's majority recommendation was that the basic rates of British Railways' salaried and conciliation staff should be increased by 3 per cent from the beginning of the first full pay week following November 26, 1956. This recommendation was in line with the award made following a claim towards the end of last year by the Associated Society of Locomotive Engineers and Firemen. The conclusion reached in this majority finding was that "the only ground upon which an increase in basic rates could be justified was that of the increased cost of living." That finding was not supported, however, by Mr. Hall. In a minority report, included in the tribunal's award, Mr. Hall said that both sides agreed that there had been an increase in productivity on the railways, and that that increase was continuing, and part of the N.U.R. claim was to share in the volume of increased productivity. That part of the claim, Mr. Hall urged, was fair and reasonable and should be expressed in the form of an addition to the 3 per cent.

Following the announcement of the tribunal's award, there were discussions between representatives of the British Transport Commission and of the National Union of Railwaymen. These talks lasted two days, and last Friday evening it was stated that agreement had been reached. The Commission has agreed to a wage increase of 5 per cent as from March 4, an amount which is acceptable to the N.U.R. A statement issued after the settlement said that account had been taken of the growing productivity and efficiency of the railways. Since the establishment of the British Railways Productivity Council in 1955, the statement continued, there had been a growing realisation among the railway staff of the change in outlook needed to make modernisation of the railways a success, and an increasing willingness to accept the changes inherent in the new developments. The N.U.R. has undertaken to give consideration to proposals for periodical reviews of wages and conditions. At reviews of this nature between the unions and management, it has been urged, all factors affecting the remuneration and conditions of the staff, including changes arising from the modernisation plan and increasing productivity, could be brought under joint examination in a spirit of mutual confidence and trust.

The Iron and Steel Industry

At the annual general meeting of the British Iron and Steel Federation, on March 19, Sir Andrew McCance, the president, said that, by next year there should be capacity for the production of 24,000,000 ingot tons of steel. Thereafter, he added, demand for steel might continue to rise by at least 1,000,000 tons a year.

Referring to the present and future stages of the industry's development plan, Sir Andrew stated that fourteen new blast-furnaces were projected, supported by additional coke ovens, ore preparation plants and sintering facilities. The productivity of existing furnaces would also be further improved. As a result, it was expected that by 1962 there would be capacity for about 20,000,000 tons of pig iron and ferro-alloys. Furthermore, eight new or extended melting shops were planned, and the capacity for finished steel products would be substantially increased both by the building of new mills and by greater throughput of steel at existing plants.

On average, Sir Andrew continued, the industry would have to spend about £100,000,000 a year on the development programme. Steel prices must therefore be adequate to sustain continuing expenditure on such a scale. The steel would be made, Sir Andrew commented, but its price must be economic and must take account of the high cost of the new equipment required. The Government could also help, he said, through its taxation policy and in particular by restoring the investment allowances.

Overseas Trade

The report on overseas trade in February, prepared by the Board of Trade, shows that, following the trend of recent months, the figures were somewhat distorted by the disturbance of normal shipping movements following the closing of the Suez Canal. Exports in February were valued at £278,200,000, a figure £17,000,000 or so higher than that computed for January. The value of imports was £320,800,000, which was £56,000,000 below the high figure returned for January. Re-exports were valued at £10,900,000.

The Board of Trade says, however, that in view of the distortion of the figures in each of the four months since the closing of the Suez Canal, the most reasonable basis for assessment of the latest trends in the United Kingdom's overseas trade is to consider the November-February period. Over that period, the monthly average value for imports was £330,000,000, which was about 1 per cent above the monthly average from March to October last year. From this, it is deduced that the general stability of the total value of imports at the level reached in 1955 has continued. But this stability, the Board of Trade points out, covers a rise of 4 per cent in import prices in the last four months, compared with a year earlier, oil prices and freight charges having contributed largely to the increase. The average monthly value of exports in the four months, November-February, was £271,000,000, which was 2 per cent above the average for the period March-October, 1956. The upward trend of exports has therefore been maintained, although the advance has been rather less than the underlying rate of growth of 10 per cent a year which prevailed through most of 1956. In the last four months, export prices were about 4 per cent higher than a year ago.

As to the commodity pattern of trade, the Board says that exports of metals did well throughout last year and averaged over £39,000,000 a month in the four months ended February, 1957, an increase of 10 per cent compared with a year earlier. Continuing the trend which developed in the second half of 1956, exports of engineering products in recent months have been less buoyant than exports of metals. Last month they were valued at £105,000,000, which was about 5½ per cent higher than a year earlier.

Manufacturing Costs

Some comments on the danger of any rise in the level of manufacturing costs were made last week by Mr. L. E. Mather in his chairman's address at the annual meeting of Mather and Platt, Ltd. He pointed out that the trade unions were pressing for wage increases, there was a warning that there might be advances in the price of certain raw materials, and local taxation in the form of rates on property was likely to be greatly increased. All these things, Mr. Mather said, in addition to the burden of high Government taxation, added up "to the possibility of our being priced out of markets."

Wage increases, if excessive, Mr. Mather continued, defeated their own ends. They increased the cost of living for the whole community. If prices were held when wages were increased, profits were reduced and shareholders suffered. Such shareholders were for the most part in receipt of fixed incomes, or were institutional bodies like investment trusts and insurance companies whose members themselves were in the fixed income class. The best way to improve earnings, Mr. Mather urged, was by increased productivity which, through incentives such as piecework or output bonus, provided rewards which, at the same time, tended to secure a bigger share of trade from world markets.

Trade with South Africa

Details were given last week, at a press conference organised by the Federation of British Industries, of plans for an Anglo-South African trade drive to begin next month. It is being sponsored by the F.B.I. and the British Manufacturers and Representatives Association of South Africa, with the support of the Board of Trade, the Central Office of Information, the British Council and other interested organisations, and the main aim is to remind the peoples of both nations of the important trade links between them. In 1956, the United Kingdom was the best market for South African exports, whilst South Africa was rated the fifth best market for United Kingdom exports.

Three "trade weeks" to be held successively in the areas of Cape Town, Durban and Johannesburg, form the core of the proposed drive. The first of these, which it is proposed to hold in Cape Town and Cape Peninsular, from April 29 to May 4, will follow the jubilee banquet of the B.M.R.A., which this year celebrates its foundation in South Africa fifty years ago. The second trade week will be held in Durban and Natal in late June, and the third in Johannesburg, in September. The F.B.I. states that its scholarship scheme, which brings promising young engineers to the United Kingdom for study and training, has been extended to South Africa from 1957. Supporting arrangements to the general programme include the showing of educational and documentary films, and films about British industry. Exhibitions and displays of British merchandise and of South African goods made from British materials will be staged by the largest shops and department stores.

Development and Growth of the Australian Steel Industry

THREE events stand out in Australia's history, three dominant events which opened up completely new phases in the development of the nation. Each contributed variety to Australian living. And each in its turn brought great new spurts in the rising strength of Australia's national economy. The first was the introduction of the merino sheep in 1804. With its ability to feed in low rainfall areas, the merino sheep made possible the development of the open country behind the coastal ranges. Discovery of gold in 1851 was the second signal event. The news of this discovery awakened the peoples of the Old World to the new land of opportunity, touching off the first large immigration flow to Australia. With them came much bigger trade and commerce in the rapidly expanding port settlements. In April, 1915, the first steel was tapped from the newly erected furnaces at the Newcastle Works of the Broken Hill Proprietary Company, Ltd., an event which marked the beginning of Australia's large-scale industrial development. Lacking an adequate local source of steel—the basic industrial raw material—Australia had until then acquired only building, textile and other light industries. In 1915 there were 70,000 people employed in industries processing metals. To-day there are over 400,000. From only 12 per cent of the total factory working force in 1915, the proportion of those working in metal-based industry has grown to 40 per cent—a clear indication of the great upsweep in manufacturing that has followed the first large-scale production of steel in Australia. This was an industrial revolution of a new kind. In the older economies, cheap mass-produced steel first became available when extensive industrialisation had already taken place. The technical knowledge and industrial background gained in processing iron for centuries, provided the foundation on which many steel-based industries quickly grew. Australia's industrial revolution has been in comparison quite remarkably sudden. To-day, a large number of manufacturing enterprises, employing together more than 1,000,000 persons, produce the bulk of the manufactured goods used in Australia. And the gaps are steadily being filled. Australians take this situation for granted. Yet it is not unusual to find Australia still regarded overseas as a primarily rural nation, and this in itself reflects the rapidity of her industrial progress.

The B.H.P. Group of companies provides a strong foundation for Australia's manufacturing economy. It is a position of high responsibility, for if the steel industry were not successful, then the future of thousands of other manufacturers would be jeopardised. The rapid growth and prosperity of Australia's secondary industries reflects the steel industry's own growth and strength. To-day, the B.H.P. Group is a family of twelve companies, engaged primarily in the manufacture of iron and steel, but also making a variety of products ranging from nails to ships. In addition, there are two sub-subsidiary companies, Southern Portland Cement, Ltd., and the Lysaght Durham Chemical Company, Pty., Ltd. With an ingot steel capacity of 2,250,000 tons, the group's major steel plants produce the bulk of Australia's basic steel needs. Production in 1955 represented 502 lb of steel per head of population, a figure exceeded in only four other countries in the world. Despite all the difficulties of a large-scale plant expansion in the post-war period, the group's production since 1950 has expanded at a faster rate than that in the United Kingdom or the United States. The Australian steel industry is owned in the main by Australians, no less than 41,300 individual shareholders having an interest in the B.H.P. Company, Ltd. This number includes many financial institutions such as life insurance companies and societies, which act as trustees for the savings of millions of Australians. There are many thousands of businesses, both small and large, in Australia, which supply the industry with its multitude of needs. Over £23,500,000 was spent by the group last year in purchases, and this continued expenditure plays a vital part in the business of the great number of Australian supplying firms. The life-blood of the industry, its employees, to-day number 30,000, and they receive approximately £30,000,000 in earnings each year. The average earnings, approximately £20 a week, compares with the overall average for Australian industry (as indicated by official statistics) of £16 8s. per week. Although the cost of living has risen sharply since 1945, the average earnings of the group's employees has risen faster. The cost-of-living index in 1955 had risen 111 per cent since 1945, while the average earnings of steel workers have risen by 174 per cent. Naturally, these incomes form a basic economic force, especially in the districts where the company's operations are centred. As an example, in the Newcastle area alone, the weekly wage bill for employees of the B.H.P. Group itself is over £250,000. If the wages and salaries of those working for firms supplying the steel works and those using steel as a raw material are added to this, the importance of the industry to the prosperity of hundreds of thousands of Australians is apparent. At the head of the group is the oldest company, the Broken Hill Proprietary Company, Ltd. It is the story of a company which, from simple beginnings, became Australia's major industrial enterprise—a development made possible only by the far-seeing vision of a few enterprising Australian pioneers.

The Pre-Steel Era

The name of the company is taken from the early association with the famous silver-lead-zinc city of Broken Hill, on the western boundary of New South Wales. This rich lode was discovered by a boundary rider, Charles Rasp, in 1883. That simple act started an amazing cavalcade of events. One of the results was the formation of The Broken Hill Proprietary Company, Ltd., in 1885, to work this mineral lode. Out of this activity grew the city of Broken Hill and the lead smelters at Port Pirie, in South Australia. The company's mine was worked for fifty-three years, during which it attained world-wide reputation. (On being worked out it was closed down in 1939 and thus the company to-day has no connection with Broken Hill or the silver-lead-zinc industry.) The company erected smelters at Port Pirie to smelt the ore from the "Proprietary" mine and it was in prospecting for ironstone—a flux needed in lead smelting—that the rich deposits of this mineral in the Iron Knob area in South Australia were discovered. With the knowledge that its Broken Hill deposit was not limitless and having this great new raw material asset, the directors examined the question of embarking on iron and steel manufacture. The late Mr. David Baker (a leading American iron and steel authority) was engaged to come to Australia and report on the company's proposed venture. He recommended that it proceed and selected the site on which the Newcastle Steel Works now stands. He was attracted to the area by its close proximity to rich coal fields and the adjacent deep water anchorage.

Steel Production Begins

The work of reclaiming the then swampy site began on January 3, 1913. Thousands of piles were driven to provide a firm bearing for the plant. From the outset careful provision was made for future expansion and even though the first units installed were small by present-day standards, they represented the essential nucleus of an integrated, balanced and large-scale plant. The shortage of steel from overseas, experienced during World War I, quickly showed the advantages of this far-sighted approach and the initial plant units of one blast-furnace and two open-hearth furnaces were added to rapidly. By the end of 1921, the works had three blast-furnaces and seven open-hearth steel furnaces and rolling capacity had been expanded by the addition of two further mills. However, in those early days the plant faced many difficulties. Inevitable "teething" problems and severe competition from imported steel had to be overcome. Steel poured into the country and had it not been for the enthusiasm of the comparatively small band of men, the great venture into steel would have failed. The answer came from a vigorous pursuit of efficiency, investment in good plant and raw materials. A highly efficient low cost industry emerged, allowing prices to be lowered, with obvious advantages to Australia's steel-using industries. In 1928 a new company, Australian Iron and Steel, Ltd., had been formed by Messrs. G. and C. Hoskins, in conjunction with an Australian and two British firms. The Hoskins brothers had been associated with pioneering effort to establish an iron and steel industry at Lithgow, New South Wales. However, the inherent unsuitability of this site had forced the removal of this enterprise to Port Kembla. This was designed to become a large-scale works in due course. In 1935 B.H.P. acquired all the ordinary shares of A. I. and S., which became the principal subsidiary. Costly overlapping and duplication of plant was eliminated thereafter and an extensive programme of development of the A. I. and S. Kembla Works began. By the end of 1941 ingot steel capacity at the Kembla Works had reached 700,000 tons annually and that of the B. H. P. Steel Works was 1,000,000 tons. The value of the development of the steel industry in these pre-war years was immediately brought home to every Australian when World War II broke out. The full resources of the industry were placed at the service of the nation. Numerous developments and innovations were made necessary by wartime shortages, although substantial expansion was halted. After the war, expansion was resumed, and since then £67,000,000 has been spent. The focal point of this programme has been at the Kembla Works of A. I. and S., Ltd.

The Industry To-day

Operations of the industry to-day are Australia-wide, with substantial units of plant in every State of the Commonwealth. However, these operations naturally focus around the Iron and steel works at Newcastle and Port Kembla. To-day, the Newcastle iron and steel works of the Broken Hill Proprietary Company, Ltd., is a completely integrated unit, with an annual capacity of 1,000,000 ingot tons. A substantial modernisation programme over the years has improved productive efficiency. The main items of plant now consist of: four batteries of Wilputte by-product coke ovens—one now being rebuilt; three blast-furnaces; fourteen open-hearth furnaces and two smaller open-hearth furnaces for the production of steel for rolls, special ingots and castings.

The plant includes a wide range of rolling mills. These comprise: one bloom mill, a rail and structural mill, continuous billet and sheet bar mill, one medium bar and two merchant bar mills (one of which also produces skelp for processing into pipes and tubes), a plate mill, a rod mill and a narrow-width cold rolled strip mill. The Newcastle plant, following the rationalisation of production between the two iron and steel works, has tended to specialise in the very wide range of merchant steels and semi-finished steel products used by nearby subsidiary and allied industries. It is for this reason that Newcastle has been chosen as the site for a new skelp mill, which will produce high quality steel strip for subsequent processing into pipes, together with medium-width skelp for a variety of other applications. The Newcastle Steel Works undertakes a number of activities ancillary to iron and steel production. These are activities not normally undertaken by overseas steel plants, which have ready access to supplies from outside specialist firms. They include the manufacture of ferro-alloys, iron and steel castings and the rolls used in the shaping of steel, together with plants for the manufacture of tungsten carbide, and basic refractories. The works also contains a large number of maintenance shops in which a wide range of engineering is carried out.

Around the Newcastle Steel Works has arisen a wide range of complementary industries, some subsidiary, some associated, and some, again, independent engineering or steel fabricating firms, making Newcastle one of the most important industrial centres in Australia. At the Newcastle Steel Works alone, the B. H. P. Company, Ltd., employs 8630 persons, earning wages of over £178,000 a week. As the first large-scale steel works of Australia, the Newcastle works continues to play a most important role in the industry's operations, a role which is destined to grow with the nation's needs. Operated by Australian Iron and Steel, Ltd., the steel works at Port Kembla, following the post-war expansion programme, has now attained a basic ingot capacity of 1,250,000 tons a year. This will jump to 1,600,000 tons in the second half of this year, when new open-hearth plant, now under construction, is completed. At the present time the basic units of plant comprise : two batteries of Wilputte by-product coke ovens ; three modern blast-furnaces ; eight basic open-hearth furnaces (with a further two under construction) ; an electric steel plant, with a capacity of 31,000 tons a year.

Rolling mills comprise a bloom mill, heavy structural and rail mill, continuous billet mill (including breakdown mill), and two merchant mills (No. 1 handling heavier sections and No. 2 a range of products including rods, general sections and skelp). The most recent addition is the hot strip and plate mill. The installation of this unit represented the biggest single project ever undertaken by any Australian industry and provides a capacity for rolling plates and flat strip of well over 1,000,000 tons a year. A spun iron pipe plant, comprising four centrifugal machines, produces large pipes for public undertakings. New construction includes a tinplate plant, the No. 2 open-hearth shop mentioned above, a large-capacity slabbing mill to provide feed for the hot strip and plate mill, and a sinter plant. The greater part of the industry's post-war expansion has taken place at the Port Kembla Steel Works. To-day, it is a large integrated plant ; with further expansion now under way and planned it will become one of the largest integrated steel plants in the British Commonwealth. At present, employment at the works totals 9130 persons, earning over £180,000 in wages and salaries each week. Rapid expansion of the steel industry in the Wollongong/Port Kembla area has been the principal factor in the growth of the city of Greater Wollongong, and the continued increase in production facilities planned to take place will ensure that this complementary growth continues.

Iron Ore Quarries

The industry obtains the great bulk of its iron ore requirements within the country. Following a recent development, however, a small proportion of ore from New Caledonia will be used. Operated by B.H.P., the iron ore quarry at Iron Monarch, 34 miles inland from Whyalla, on the west coast of Spencer Gulf, South Australia, currently supplies the major proportion of the industry's needs, output at present being nearly 3,500,000 tons a year. Developments now being undertaken in this area, which include the opening up of the nearby Iron Baron deposit, will raise output. Ironstone is quarried at Iron Monarch by cutting benches at about 100ft intervals down from the summit of the hill, all operations being executed mechanically by electric shovels and locomotive-hauled trucks. Other plant consists of crushers and ore storage and loading facilities. The ore is transported to Whyalla by rail, where it is unloaded into ore storage and ship-loading facilities. In the fifty-six years in which they have worked, the Iron Knob–Iron Monarch deposits have supplied over 60,000,000 tons of ironstone. Operated by Australian Iron and Steel, Ltd., the industry's second source of iron ore is at Cockatoo Island in Yampi Sound, Western Australia. Here the the whole of the quarrying, crushing and ship-loading equipment is electrically operated, with ore being transferred by diesel trucks from the electric shovels to the crushing and ship-loading installations. The first work of preparation for quarrying was commenced just before the beginning of 1941, but because of war it had to be abandoned in the following year. It was not until September, 1944, that it was possible to resume work. While this was proceeding the industry undertook the design and construction of suitable ships to transport the ore on the long sea voyage to the eastern coast steel works. The first shipment took place in July, 1951, and since then the island has supplied an important proportion of the industry's ore needs. Output will rise to a figure above 1,000,000 tons a year when sintering facilities are completed at the Port Kembla Works.

Coal Mines

The association of iron and steel manufacture with coal and its derivative coke is well known. As the second main raw material, its assured supply is a vital prerequisite to the establishment of large and costly plant. And it was the presence of large nearby reserves of high-grade coking coal that principally determined the selection of Newcastle and, in turn, Port Kembla, as sites for the industry's main works. Soon after the Newcastle Works was established plans for expansion were being considered and it was clear that the success of these plans depended on assured and adequate supplies of coal. Thus, the B.H.P. Company, Ltd., undertook a long-range plan of colliery development, and its first colliery, John Darling, was established in 1927. The colliery's normal output is 1800 tons a day, extraction being by both mechanical and hand methods. Other collieries operated by B.H.P. on the Newcastle field are Burwood Colliery and Lambton Colliery, both of which were purchased in 1932. Output from Burwood is 2300 tons a day (one of the largest in Australia) and from Lambton is 750 tons a day. The Stockton Borehole Colliery was acquired in 1949 and as a result of extensive mechanisation output is currently 770 tons per day. The company is also associated with Hebburn, Ltd., in B.H.P. Collieries Pty., Ltd., which owns and operates Elrington Colliery on the Maitland field. This coal, however, is more suitable for gasmaking than for metallurgical coke manufacture. Australian Iron and Steel, Ltd., owns and operates five collieries on the South Coast field. Almost all of the coal mined is mechanically cut and loaded, following the industry's big expenditure on equipment over recent years. The interest of A.I. and S., Ltd., in the field began in July, 1928, when the Wongawilli Colliery was purchased. To supplement supplies of coal from this colliery the company bought in turn Bulli (1936) and Keira, now known as Kemira Colliery (1937). In 1946 an entirely new fully mechanised mine, Nebo, was opened and Mount Kembla Colliery was purchased. Until 1938 the company's mines were all hand-worked, but thereafter mechanisation steadily replaced the old methods.

Limestone and Dolomite

Limestone, the third principal raw material used in the smelting of iron ore, and dolomite, the fettling material for open-hearth steel furnaces, are both obtained in South Australia at quarries worked by the B.H.P. Company, Ltd. A further source of limestone is the deposit at Marulan, 74 miles from Port Kembla and operated by A.I. and S., Ltd.'s subsidiary, Southern Portland Cement, Ltd. Rapid Bay plant incorporates many of the best features of the Iron Monarch and Whyalla iron ore mining and handling equipment. After blasting, limestone is loaded by an electric shovel into side-tipping trucks, which are then drawn by electric locomotives to the crushing plant. The material is loaded into ships via conveyor belts over the company's jetty. Until 1940 Rapid Bay was merely an unfrequented spot on the eastern shore of St. Vincent's Gulf. To-day it is a compact settlement in an attractive setting of sea and hills, with a population of 250, living in comfortable modern homes, with a well-equipped school and sports ground. Dolomite is obtained from Ardrossan, on the western shore of St. Vincent's Gulf. The dolomite deposits outcrop about three-quarters of a mile south of the township, which, for many years, has served as a shipping port for grain growing in the surrounding district. When the company decided in 1948 to develop the dolomite deposit it erected a crushing plant and a jetty, 3030ft long, for loading the material into the industry's ships. Since 1953 this loading gear has also been used for bulk loading of grain and salt, marking yet another example where the steel industry has directly assisted other local industries.

Whyalla

Whyalla, on the west coast of Spencer Gulf, South Australia, as mentioned above, serves as the port for shipment of iron ore quarried at Iron Monarch. But ever since 1937 Whyalla has been much more than a shipment port for ore. The Broken Hill Proprietary Company, Ltd., has erected a number of important industrial units there, which play a major role in Australian heavy industry. One of the principal industries conducted at Whyalla is shipbuilding. The largest in Australia, the Whyalla shipyard, has five building berths and is capable of handling ships up to 22,000 tons deadweight from drawing board to fitting-out and sea trials. With the launching of S.S. " Iron Spencer " on May 23 last, the shipyard has built twenty-seven vessels. Of these vessels, eight have been built for the company's own fleet, including the four " Yampi Class " vessels of 12,500 tons—the largest yet built in Australia. Transport is one of the more important elements in the efficient operation of the steel industry, and the fact that the industry has its own yard, capable of producing ships to its exact needs, has helped considerably in the industry's huge post-war expansion programme. No less interesting than the shipyard itself, is the gear and heavy machine shop. This houses a range of large precision tools capable of performing the intricate operations needed to manufacture the heavy units of ships' propelling machinery and other complex machine parts. As an example, marine gears up to 12ft in diameter can be machined. Another of Whyalla's important installations is a blast-furnace, which was blown-in on May 26, 1941, and which provides iron for the bulk of Australia's foundry needs. The furnace has a capacity of 700 tons of basic pig iron (or 575 tons of foundry pig iron per day). Production of steel in the electric furnace at Whyalla began in 1949. The plant comprises a steel-framed electric melting shop which also houses the steel foundry. With a capacity of 14-ton heats, the electric furnace contributes to the industry's production of spring steels. The main products of the steel foundry are castings needed for quarrying operations at Iron Monarch and elsewhere. To-day, approximately 2300 persons are employed in the various installations at Whyalla itself and at the quarries in nearby Iron Monarch, and they earn wages of over £41,000 per week. The township is prosperous and pleasant and an outstanding example of how Australian enterprise can convert seemingly unpromising areas.

Shipping Organisation

Sea transport plays an important part in the operations. The industry's coastal trade accounts for approximately one-third of the entire inter-State transport of goods around the long Australian coastline. The industry's shipping fleet is operated by the B.H.P. Company, Ltd., and is the largest privately owned shipping service in Australia. It consists of fifteen vessels, of which two are under charter, with a total deadweight capacity of 135,000 tons. Expansion of the fleet is continuing, and a further vessel of 10,000 tons deadweight, S.S. " Iron Spencer," is expected to be commissioned immediately. It was recently decided that the company will build two 19,000-ton deadweight ore carriers.

Kwinana

Now near completion at Kwinana, Western Australia, is the new steel rolling mill being erected by the B.H.P. Company, Ltd. This plant will involve an expenditure of almost £4,000,000, and will become another major unit of the industry in Western Australia. The rolling mill will produce a wide range of merchant steel sections, and will have a capacity initially of 50,000 tons a year. The mill is served by a modern jetty, and is the second major industry to be established in the area. It adjoins the oil refinery of B.P. Refinery (Kwinana), Ltd.

High-Voltage Surge Generator

Since its installation of an experimental 400kV surge generator in 1950, Forges et Ateliers de Constructions Electriques de Jeumont has considerably expanded its facilities in the field of high-voltage testing. By the time the new French standards for surge tests of transformers came into force on July 1, 1951, Jeumont had commissioned a Marx-type surge generator which achieved a peak voltage of 2,400,000 volts and a power of 23kJ. This generator was equipped with twelve condensers of 0·11μF each, which were charged at 200kV.

With the continuing growth of electricity consumption in France went the construction of high-voltage transformers of increasing size, until, in 1956, the company built transformers for 150kV or 220kV, and 150MVA. For such units the 23kJ generator was no longer capable of providing the correct waveform and, accordingly, an order was placed with Etablissements E. Haefely et Cie., Basle, for a plant having a capacity of 104kJ and giving a peak tension of 2,400,000V. This plant, which came into service in August of last year, is stated to be the most powerful equipment at present in use in Europe. It is suitable for transformers of 380kV, 300MVA, and can be used for tests on equipment designed for up to 400kV.

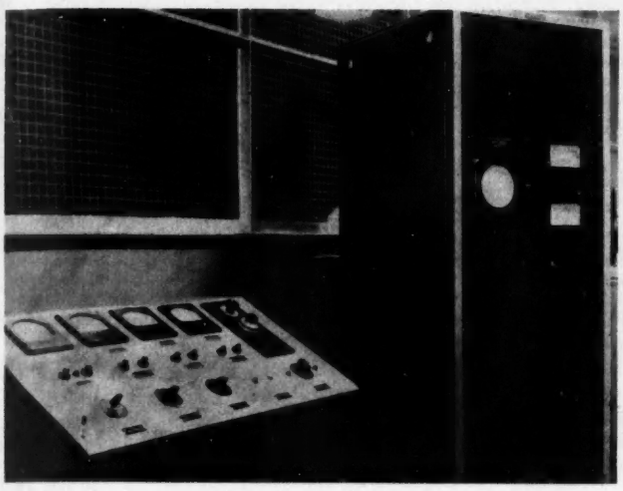


Fig. 1—Control desk (left) and oscillograph (right). On the top right-hand corner of the control panel may be seen the double-potentiometer voltage control and the 0 deg. to 360 deg. phase shift

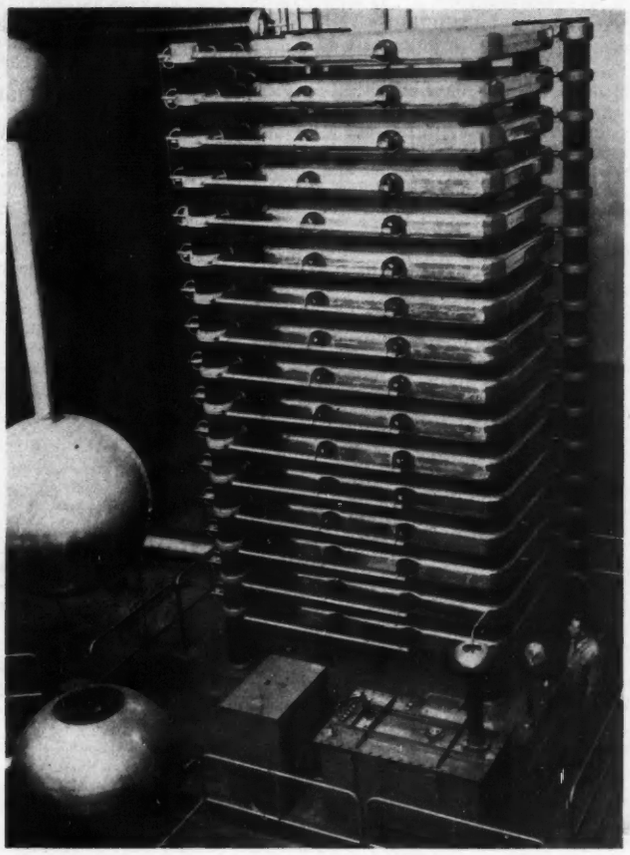


Fig. 2—2·4 million volt, 104kJ surge generator. In the foreground, an infinitely variable transformer (left) feeding an h.t. charging transformer and selenium rectifier (right), which has an output of plus or minus 150kV

The generator, shown in Fig. 2, possesses sixteen stages in cascade. Each stage comprises four 0·58μF condensers, of which two and two are connected in series. Each condenser is charged to 75kV so that the tension per stage is 150kV. The condensers are of aluminium foil with a paper dielectric immersed in an oil bath, the tank housing the condenser being hermetically sealed. The series connection between pairs of condensers is made by contact between the tanks and all tanks are interconnected by resistances so as to fix their discharge potential.

The power stored, 104kJ, corresponds to a short circuit current of 45,000A. Charging is carried out by means of a high tension transformer in series with a selenium rectifier of novel design, giving ±150kV d.c. The transformer primary is supplied from a 0–240V continuously variable transformer fitted with remote control. Both transformer and rectifier are oil-immersed in the same tank. The equipment is remarkably compact for its power and output voltage.

Operation of the installation is entirely by remote control, no power circuits passing through the control desk (Fig. 1). Connection between the desk and the generator is by three flexible cables, each of which contains twelve wires. Thanks to this arrangement, the control desk can be placed anywhere in the hall, thus improving safety and permitting the best possible view of the test.

The generator is electronically controlled with an accuracy of 5 per cent by means of a double potentiometer on the control desk. This method makes possible a rapid variation of the test voltage and acts as a safeguard against mistakes by the operator. The impulse which triggers the generator also unblocks the sweep of the cathode-ray oscillograph which is fitted with a variable time delay. A phase-shift device, operating from 0 deg. to 360 deg., makes it possible to apply successive surges, always at the same point of the 50 c/s wave, which is of importance in the testing of transformers which are to undergo a surge test while under normal working tension.

The layout of the generator allows the condensers to be connected in various ways by means of connector bars, without changing any resistances thus obtaining working ranges of 150kV, 600kV, 1200kV and 2400kV with capacities, respectively, of 9μF and 2400kV with capacities, respectively, of 9μF and 570,000pF, 142,000pF, and 36,000pF. This large range of voltages is required for testing, in addition to inductive equipment, such non-inductive items as H.T. cables and surge arresters.

Heavy Water Separation Process

It is announced that the German Federal Ministry for Atomic Energy has placed a research order with Pintsch Bamag Aktiengesellschaft, of Butzbach/Hessen, Germany, for the expansion of development work regarding the production of heavy water by hydrogen sulphide/water exchange and similar processes.

Heavy water, graphite, or beryllium, are used in natural uranium and breeder reactors as moderators for the reduction of neutron losses. Nuclear reactors are estimated to require 0·5 to 1 ton of heavy water per megawatt effective capacity. According to investigations of OEEC, the co-operating countries of Western Europe intend to install at least 3000MW in atomic power stations until 1965, and 10,000MW until 1970. The bulk of these reactors is expected to operate on natural or slightly enriched uranium with graphite or heavy water as moderator. Assuming that only one-third of the atomic power stations installed by 1965 will use heavy water, a demand of 500 to 1000 tons until 1965, and 1500 to 3000 tons for the following five years may be expected. The OEEC thus assesses the demand of Western Europe to be approximately 400 tons per year from 1965 onwards. According to the German Atomic Commission the demand of Western Germany in 1965 to 1970 will amount to 100 to 200 tons per year.

The production of heavy water utilising the temperature-dependent deuterium equilibrium for hydrogen sulphide and water, was already subject of experiments by Geib and his staff in the Leuna Werke, Germany, during World War II. Afterwards it was further developed by the United States Atomic Energy Commission. Two large-scale plants were built, the first at Dana (Indiana) in 1950. A second plant was erected some years later on the Savannah River in South Carolina. Recently the Dana works have been shut down on account of difficulties due to corrosion and because its economy did not compare favourably with the Savannah River plant. The latter has a production capacity of more than 100 tons per year and enabled the A.E.C. to reduce the price for heavy water to 62 dollars per kilogramme of D_2O.

Pintsch Bamag Aktiengesellschaft started developments in this field early in 1956, using their experience gathered during the war with regard to the production of D_2O by means of water electrolysis. Important improvements are stated to have been obtained as a result of work carried out in co-operation with the institute for isotope separation of a German university. These in particular relate to the addition of certain organic substances to improve the interchange of agents. The advantage of this "main product process" lies in the use of ordinary water as raw material, while in the so-called "by-product processes" the production of heavy water is limited by the availability of deuterium-enriched hydrogen gas from other processes. A pilot plant is to be erected in the course of this year.

Computer Production of Trade Names

Searching for trade names, Philips Roxane enlisted the aid of "ARMAC," the electronic computer in the Mathematics Centre, Amsterdam, which was commissioned to produce names of five, six and seven letters which could be read and pronounced equally well in Dutch, English, French and German. In seven hours the electronic machine produced 36,000 names. The experts had their choice to make from sixty fully-typed foolscap sheets.

Continuous Mill

Last year, the new Phœnix-Rheinrohr rolling mill at Ruhrort came into operation. It is a continuous mill for semi-finished products, with a capacity of 100,000 to 110,000 tons per month, with the possibility of expanding to 150,000 to 160,000 tons. The plant produces billets in sizes from 50mm to 150mm and rounds from 65mm to 130mm. In addition, the first continuous train can produce slabs up to 380mm wide.

The layout of the mill is shown in our illustration. In the cogging stand the 5 to 8-ton ingots are reduced in two minutes in eleven to nineteen passes to 210mm to 240mm, the intake size of No. I continuous mill. After passing through the blooming shears, where they are sheared to size or divided, the blooms pass over No. 1 and No. 2 traversers to the first group of stands, consisting of two vertical and two horizontal mills. Such blooms as are not required to be rolled further are pulled out by No. 3 traverser, and after being sawn to length or cut on a 700-ton shears, are removed to storage and allowed to cool down. Other blooms are passed to the second group of stands, which consist of three vertical and three horizontal mills.

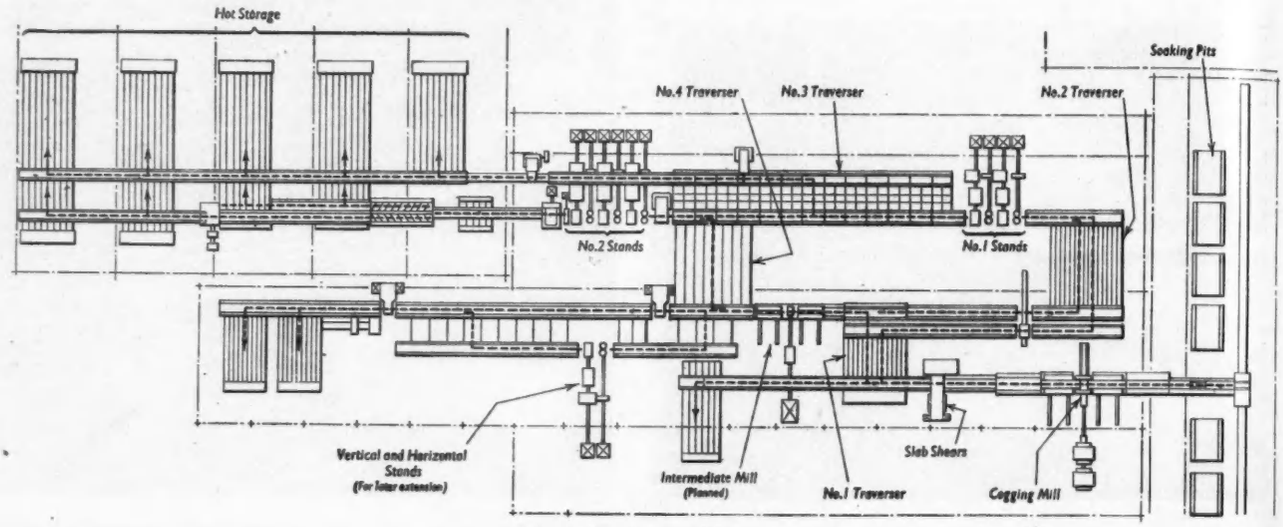
In order to expand production to the higher figure quoted above, an intermediate blooming mill can be added after No. 1 traverser. This mill will have roll diameters of 950mm and will reduce blooms from about 350mm to the size required by the first group of stands. By thus taking part of the load off the cogging mill, the intermediate mill saves a considerable amount of time, the more so as, for the last few passes, it is better to have a smaller and faster mill. The intermediate mill can, in addition, be used to produce its own output of heavy, semi-finished products. Arrangements have been made so that this mill can be added at any time without interruption of current production.

In front of No. II group of stands there are pendulum shears for trimming and dividing the blooms. Behind the mill are rotating shears, capable of dealing with 100mm billets moving at speeds of up to 4m per second, or 120mm billets moving at correspondingly lower speeds.

Of particular interest is the programme control of the cogging mill which, it is stated, is fitted here for the first time, in addition to the usual hand operation. Here, the resetting of the rolls for the next pass is carried out automatically according to a preselected schedule.

Each of the stands of No. I and No. II mills is driven by a 1650kW motor, with under-floor gearing for the vertical rolls. The hydraulically balanced top and bottom rolls can be set electrically to within ±0·1mm.

The shop in which the mill is housed measures 36m by 185m, and is equipped with a 90-ton and two 70-ton cranes. Completion of the work took five years, of which two years were occupied with planning.



Layout of continuous mill

Quarry Shovel

We have received details of the "Model D.N." excavator, which is manufactured by Menck and Hambrock G.m.b.H., Grosse Brunnenstrasse 78, Hamburg-Altona, German Federal Republic. The machine is the middle size of a series of three excavators specially developed for quarry work; special attention has therefore been paid to providing a large digging force and a large radius of action. As with all the excavators made by this firm, the underframe is a welded box construction. The excavator possesses a large diameter hoist drum with amply rated hoist brake. Controls are electro-pneumatic. A very long boom ensures a high force at the bucket-teeth in the starting position of the bucket; the latter (see illustration) has a capacity of 4¾ cubic yards and is equipped with teeth giving a low digging resistance. The door of the bucket is equipped with a brake which enables transfer of material to wagons or lorries to be made gradually and without damaging the vehicles. The electrical drive is resistance controlled, and three separate motors are provided for the joist and drive gear, the slewing gear, and the grounding gear.

Bucket of "Model D.N." excavator showing door equipped with brake for gradual discharge

International Conference on Automation

An international conference on the industrial, social and economic consequences of automation will be held in Paris from April 8 to 12 under the sponsorship of the European Productivity Agency of the OEEC. Meetings will take place at Maison de la Chimie, 28, rue Saint-Dominique, Paris (7ème).

Leading scientists, academicians, industrialists and trade unionists from European countries and the United States, and representatives of international bodies, will discuss the industrial, social and economic problems of automation and the educational implications of the need for increased numbers of technologists.

A number of industrial case studies and national reports on the present status of automation in Belgium, France, Germany, Great Britain and Sweden will enable the participants to discuss concrete experiences of automation in Europe.

Mr. V. Larock, Belgian Minister for Foreign Trade, and Lord Halsbury, managing director of the National Research Development Corporation in the United Kingdom, will deliver the opening speeches. Monsieur J. Laval, of the Compagnie Electro-Mécanique of Paris, Professor I. Svenilsson, of Sweden, Mr. W. J. Carron, president of the Amalgamated Engineering Union of Great Britain, Professor G. Friedmann of La Sorbonne, Paris, and Mr. J. F. Coales, of the University of Cambridge, will be speakers at the conference.

Welding Exhibition

During the period June 23 to July 3, the exhibition "Welding and Cutting" of the German Association of Welding (DVS Deutscher Verband für Schweisstechnik) will take place in Essen. As in 1952 and 1954, the theme will be "Welding in Production and Application," showing the development and present position of welding as well as the trend of research. Manufacturers of plant will exhibit the latest equipment, and practical demonstrations of welding and testing procedures will be given. An extensive display of welded designs will greatly add to the interest of the exhibition. Concurrently, the main DVS conference will take place from June 25 to 28. Lectures will deal with "Improvements in Efficiency and Productivity by Welding." After this congress, the International Institute of Welding will hold its annual meeting in Essen from June 29 to July 6, in connection with which there will be a series of lectures dealing with the metallurgy of welding as well as meetings of various technical committees. Details can be obtained from the Deutscher Verband für Schweisstechnik e.V., Düsseldorf, Harkortstrasse 27, and the International Institute of Welding, 29, Park Crescent London, W.1.

Progress of the Tennessee Valley Authority

BY OUR AMERICAN EDITOR

No. II—(*Continued from page 467, March 22*)

MAPPING activities, both in the T.V.A. topographic mapping programme for the Valley and in mapping for the United States Army Map Service, were continued during the year, but at a relatively low level dictated by lack of funds. Regulation topographic maps, conforming to American map standards, were completed and published for 1254 square miles of valley area. Such maps are not only useful to the T.V.A. in its various activities, but there is an increasing demand for them from private industry, State and local governmental agencies, private engineers, and other individuals. At the close of the year, topographic maps covering 35,615 square miles, or 77 per cent of the Valley area, had been issued by the T.V.A. since the mapping programme was started in 1933. Maps were also prepared for a variety of special purposes, including construction activities for locks, steam power station and other projects.

Near the end of the fiscal year, when appropriated funds had been approved, the Authority prepared to start construction of a new large lock at the Wilson dam to relieve the bottleneck that has developed as a result of the steady increase in river traffic. The new lock (Fig. 8) will reduce by about 75 per cent the time now required for tows to pass through the present facilities, consisting of a small lock at the foot of the 2½-mile-long Florence Canal, and the two locks in tandem at Wilson dam. Four to five hours are required for large tows to lock through at present, whereas the large single lift lock will take an hour or less. The lock will have a lift of 100ft, making it the highest single lift in the world, and the inside dimensions of the lock chamber will be 110ft by 600ft. The Florence Canal is to be deepened 10ft and will by-pass the present lock and dam No. 1 at the lower end.

The construction of the bridge over the Watts Bar dam was nearing completion at the close of the fiscal year, and it was opened to traffic on September 28, 1956. The T.V.A. designed the bridge and supervised its construction by the contractors. The Authority is to be reimbursed for the costs by the State of Tennessee and the United States Bureau of Public Roads.

As steam power stations have been built and placed in operation, the T.V.A. engineering staff has consistently sought to make improvements, and many of them are contributions to general steam plant engineering. Fly ash, heretofore a waste product from steam plant operations, has been under investigation by T.V.A. for possible use as an admixture for concrete. The investigations indicated that the fly ash could replace 15 to 20 per cent of the cement and a smaller percentage of sand in concrete, and it was decided to use it in the concrete mixes for the new Wilson Lock and for the new units at the Johnsonville steam power station. An appreciable saving in cost is expected.

During the fiscal year, the T.V.A. undertook to test the use of ash and slag from steam plant operation as road construction material, and several roads at the Kingston area were constructed of the materials. Indications are that the materials will stand up satisfactorily, but final conclusions await further testing of the roads over a longer period of use. At the Gallatin steam power station, special equipment was designed and installed for thawing frozen coal wagons. It consists of oil-fired burners placed between the rails and spaced so that wagons of variable lengths were provided to retain the heat against the sides of the wagons. The new equipment is considered a pilot for possible installations at Kingston and John Sevier.

It is an extremely unfortunate development that in the current long period in which no new major construction was undertaken, the Authority has lost many of its engineering employees, including a number of key men. During the year the number of engineering and construction employees dropped about 56 per cent—to 3640. However, the Authority felt that an efficient nucleus remained on which to rebuild the organisation and get any new projects under way.

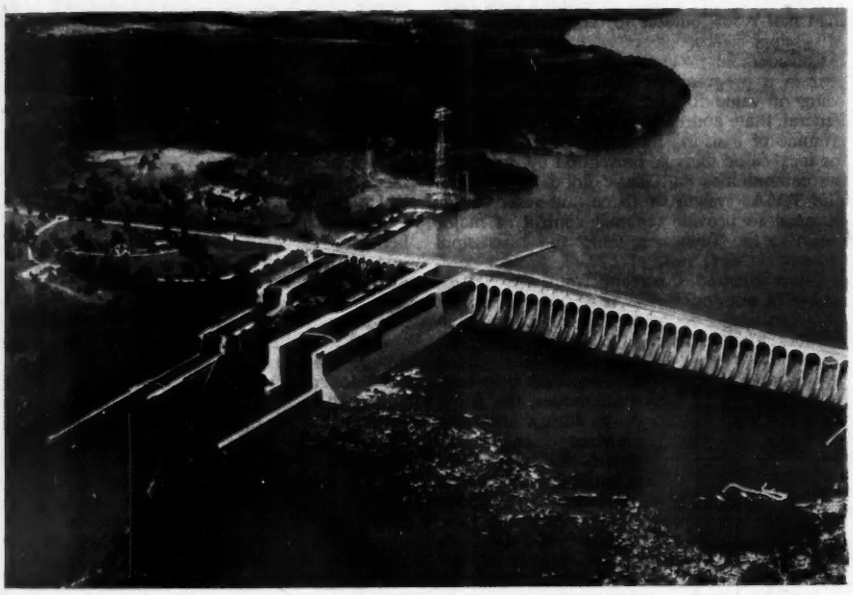


Fig. 8—Aerial view of the Wilson dam in Alabama, showing artist's rendering of new 100ft-lift lock superimposed on a photograph of the existing installation

Multiple-Purpose River Control

During the fiscal year 1956 the T.V.A. river control system coped with one of the most severe low-water periods in its history. Although several of the storage reservoirs were drawn down to their lowest recorded levels since beginning operations, the water supply was eked out to pass the crisis successfully. Channel depths were maintained and navigation was not impaired. Basic power requirements were met with the help of brief contract curtailments of interruptible power deliveries, the operation of higher cost steam-electric plants, and purchases of energy from outside sources. The low-water conditions resulted from a severe mid-winter drought coming at the end of a four-year period of less than normal rainfall coupled with continuing heavy demands for electric power. Heavy rains began belatedly in late January and continued above normal for three months, requiring flood control operations to avert nearly a million dollars of damage at Chattanooga, Tennessee, and in the lower Ohio and Mississippi River basins. The reservoirs rapidly refilled and at the end of the year the system had 1,000,000 acre-feet more water in storage than when the fiscal year began.

The T.V.A. operates a system of thirty major dams in the Tennessee Basin and one on a tributary of the Cumberland River. Of the total, T.V.A. has constructed twenty. In addition to the Wilson dam, which was originally built by the U.S. Army Corps of Engineers and transferred to T.V.A. in 1933, the Authority acquired five dams and reservoirs from a private power company. The remaining five dams, owned by the Aluminum Company of America, are operated as an integral part of the system under an agreement between T.V.A. and the company. The system provides nearly 12,000,000 acre-feet of storage space for flood control at the beginning of the flood season and additional useful storage for low-water releases to maintain hydro-electric generation and maintain navigation depths in the 630-mile channel stretching from Paducah, Kentucky, to Knoxville, Tennessee.

The T.V.A. Act directs that the dams and reservoirs be operated "to regulate the stream-flow primarily for the purposes of promoting navigation and controlling floods" and to produce electric power "so far as may be consistent with such purposes." More specifically, the system is intended to achieve "(1) the maximum amount of flood control; (2) the maximum development of said Tennessee River for navigation purposes, and (3) the maximum generation of electric power consistent with flood control and navigation." In operation, the system takes advantage of the cycle of rainfall and run-off which varies from season to season and from year to year. Over the long period in which records have been kept, rainfall over the Valley has averaged a little over 51in annually, but it has ranged as high as 62·8in (1929) and as low as 37·9in (1941).

The heaviest rainfall and the greatest run-off occur during the winter and spring months, from late December to March. It is in this period that major, valley-wide floods may occur. At the beginning of this period, therefore, the T.V.A. lowers its reservoirs to provide a minimum of 11,800,000 acre-feet of storage space. As the season advances and the danger of floods diminishes, the reservoirs are allowed to fill somewhat until March 15, when 10,400,000 acre-feet of storage is provided. After this date, when rainfall is still relatively plentiful, but major floods are no longer probable, water is stored as rapidly as possible. During the summer and autumn months, when rainfall is less and natural stream-flows decline, water is released from the reservoirs through the turbines at the power stations to maintain hydro-electric power production and navigation depths. Water released from the multiple-purpose storage projects on the tributaries not only produces power at the particular projects, but is re-used at successive power stations downstream. Water from some of the uppermost storage projects helps to power the turbines at 9 to 13 dams before it flows out of the Tennessee Basin and into the Ohio River.

At the beginning of the fiscal year 1956, the T.V.A. reservoirs held 6,880,000 acre-feet of

useful water, and of this total 82 per cent was in the tributary reservoirs and three main stream reservoirs above Chattanooga, Tennessee. At the close of the year, the useful stored water amounted to 7,910,000 acre-feet—a gain of 1,030,000 acre-feet—and 85 per cent was in reservoirs upstream from Chattanooga, Tennessee. Between these two dates, the system was operated to accomplish a number of purposes and to cope with serious problems. The long period of sub-normal rainfall and run-off which began in the spring of 1952 persisted during the first seven months of the 1956 fiscal year. The drought became most severe at mid-winter, when the normal heavy rains failed to materialise. In a period of five successive weeks during late December and early January, when weather records showed that as little as 2in of rain could be expected not oftener than once in seventy-five years, less than 1in of rain fell over the basin. Coupled with the drought was the need for hydro-electric power generation required for the large consumer use and the demands of Federal defence plants.

Before the heavy rains commenced in late January, the draught on the available water supply was so great that five of the ten multiple-purpose reservoirs on the tributaries—Douglas, Norris, South Holston, Watauga and Boone—were drawn to the lowest points since they were first placed in operation. About 57,000 acre-feet of water was drawn from Douglas reservoir in a three-week period after the level had dropped below the point where power could be generated at the Douglas power station. This water aided in supplying the hydro-electric plants downstream and in maintaining minimum levels for navigation. These operations successfully bridged the critical period until rains came in the last week of January. The rainfall continued above normal for the next three months. The reservoirs refilled at an unprecedented rate in most cases, and the Douglas, Norris and Hiwassee lakes reached or exceeded their normal guide-curve levels by the end of February. At the end of the year, the reservoir levels were higher than during the past several years, although still considerably less than the maximum permitted under the guide-curve schedules.

Flood Control

Two floods occurred at Chattanooga which, under natural conditions, would have exceeded the 30ft flood stage, but the operation of the T.V.A. system reduced them to non-damaging stages, with savings estimated at a little over 200,000 dollars. The larger of these rises, occurring on April 17, would, under natural conditions, have reached 34ft on the Chattanooga gauge, but was held to an actual 17·8ft. Since 1936, when the Norris dam went into operation, nineteen floods which would have been damaging under natural conditions, have been controlled by the T.V.A. system, with total savings of 53,518,000 dollars at Chattanooga in direct damage. Among them were what would have been the fifth, sixth and seventh largest floods of record at this point on the stream. Chattanooga is still not fully protected from possible flood damage, but during the year the city made no move toward providing the system of levees which both T.V.A. and the U.S. Army Corps of Engineers have recommended to give full protection. A flood of the size of that of 1867, the largest in recorded history, would cause damage estimated at more than 100 million dollars if it occurred to-day and were uncontrolled. The protection afforded by the T.V.A. system could reduce this damage to between 12,000,000 and 13,000,000 dollars. The T.V.A. system also makes feasible the construction of a levee system which would protect the city against a flood almost 60 per cent greater than that of 1867. Flood histories on other streams make it clear that it is quite possible that the Tennessee river may experience a flood greater than ever so far recorded, with consequent damage at Chattanooga.

The heavy rainfall in April would have caused damage at a number of other communities in the Tennessee Valley. At Cairo, Illinois, at the junction of the Ohio and Mississippi rivers, there were three rises during the flood season which exceeded the nominal flood stage of 40ft. The operation of the T.V.A. system reduced these crests by from 0·9ft to 2·1ft, with estimated savings in damage amounting to 696,000 dollars. The direct damage averted is but one measure of the benefits of flood control, others being an enhancement of land values, avoidance of special costs of protecting railways and highways, increasing the freeboard on levees and reduction of levee maintenance costs, avoidance of interruption of communications, transportation, power, and water and sanitary services, and of economic losses due to interruptions of trade and commerce. The average annual benefits of T.V.A. flood control are estimated at more than 11,000,000 dollars a year, of which a little more than half is attributable to the lower Ohio and Mississippi basins.

Considerable progress was made during the year in a programme which holds promise of being of value to other regions and to other Federal, State and local agencies. This is a programme of assisting local communities to plan for local flood damage prevention by providing the communities with basic flood information. The T.V.A. system of dams and reservoirs is designed to provide regional control of major floods in the Tennessee, Ohio and Mississippi basins. It does not, of course, protect communities situated upstream from the T.V.A. reservoirs, nor does it eliminate flood problems at all downstream communities; in some communities, local streams and local conditions cause or aggravate flood dangers. To help such communities, the Authority during the year prepared engineering reports for nine communities in the Valley providing basic flood data for their use. Nine reports had been made in previous years. About fifty communities had requested such assistance from the T.V.A. through their State planning agencies.

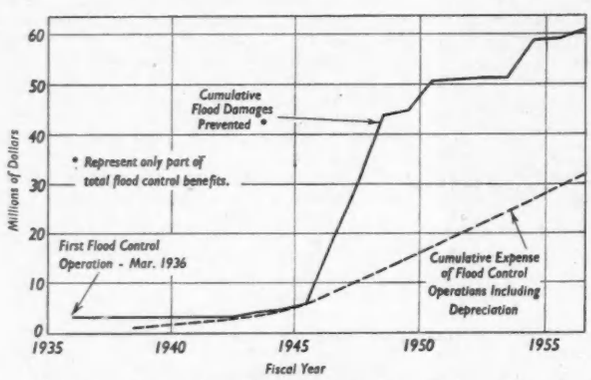


Fig. 9—Comparison of cost of, and benefits obtained from T.V.A. flood control operations since 1936

As a part of this programme, T.V.A. co-operated with the city of Lewisburg, Tennessee, and the Tennessee State Planning Commission in making a "pilot" study to determine the most economical solution to the community's flood problem. The study was published by the State and made available to other communities and States for use as a guide in planning for flood damage abatement. The Tennessee State Planning Commission also published and distributed to various planning agencies, officials and individuals, a paper, "Food Problems and Their Solution Through Urban Planning Programmes." The T.V.A. programme provides a means of putting into the hands of local communities in usable form the vast amount of rainfall, run-off and other flood control data which the T.V.A. has amassed in connection with the construction and operation of its region-wide system. Many of the communities have used the data to zone out residential development in flood hazard areas. Industries have used the reports in seeking flood-free works sites. A number of Federal agencies concerned with the financing of local improvements are using this information on an increasing scale.

River Navigation

The traffic on the Tennessee River in 1955 exceeded the predictions for "matured" traffic which early studies of the waterway expected in 1960. The volume continued to gain during the first six months of 1956. The savings in transport costs, estimated at 16,700,000 dollars, were 85 per cent above the predictions for 1960. Nearly 10,000,000 tons of freight moved on the Tennessee River in 1955. In comparison with these figures, an estimate based on a study made by T.V.A. in 1940 indicated "matured traffic" of 7,000,000 tons in 1960. The traffic during the first six months of 1956 was estimated to be greater than for the same period in 1955 by 19 per cent in tonnage and 33 per cent in ton-miles. The cost of maintaining the waterway amounted to about 3,900,000 dollars in 1955, leaving a margin of transport savings over costs of 12,800,000 dollars. This margin represented a return of more than 9 per cent on the net navigation investment of 139·5 million dollars.

All the major commodities moving on the river showed an increase over the year before, except iron and steel. A record of 89,000 tons of automobiles were transported by barge from Ohio River ports to Guntersville, Alabama, for distribution throughout the south-east. Grain shipments were increased as three new grain terminals at Knoxville and at Chattanooga came into use. A large amount of construction was under way on waterfront works and navigation terminals. Since 1933, it is estimated, private industry has invested more than 500 million dollars in about seventy-five terminals and works along the lake shores.

A striking indication of the development of recreation activity on T.V.A. lakes is the large increase in numbers of pleasure craft. Figures which became available for the boating industry for the first time during the year showed that between 1947 and 1955 the number of recreational craft in the United States had increased by about 127 per cent. In the same period, the number on the T.V.A. lakes rose from 9615 to 35,431, an increase of nearly 270 per cent.

Despite the fact that poor water conditions during the autumn and winter required the draw-down of several reservoirs to the lowest points on record, little if any harm seemed to be done to the fish population, even in the Douglas reservoir, which was virtually emptied. Population checks on several reservoirs indicated that reproduction was satisfactory. Spring fishing on the Norris, Cherokee and Douglas reservoirs, where the draw-down was most drastic, was reported to be as good as the year before. T.V.A. biologists, in co-operation with the biologists and game conservation officers of five States, conducted thirty fish-population studies on six main stream and nine storage reservoirs as a part of a series that was initiated in 1941. The studies involve killing the fish in small sample areas and then identifying, weighing and measuring them, and taking scale samples. The studies help to keep track of fish-population trends, to determine conditions of health and growth, and to lay a factual scientific foundation to guide State agencies in fisheries management and regulation. One of the results of these studies, initiated by T.V.A., has been the increased interest of the States in fisheries investigations. All seven of the Valley States now employ fisheries technicians on active research programmes, and they contributed more than twice as much time to the population studies in the fiscal year 1956 as did the T.V.A. staff members.

The check this year revealed good reproduction and a desirable distribution of different species on all the reservoirs except two smaller ones which have become polluted by domestic sewage and industrial waste. It also showed that in the main stream reservoirs non-game species still account for three-quarters of the population, indicating the continued need for commercial

fishing. Tagging operations continued to show that most fish are not caught. On five storage reservoirs less than 16 per cent of tagged fish have been caught on the average over the past ten years, and on three main stream reservoirs the proportion was less than 4 per cent.

Power Generation

For the fifth consecutive year, the dominant aspect of the power production programme was the heavy growth of generation required to meet the demands of atomic defence plants. T.V.A. power deliveries to the Atomic Energy Commission and other Federal agencies grew much more rapidly than deliveries to all other consumers combined. For the second consecutive year these agencies used more than half of all the power T.V.A. sold. The following table shows the year-by-year increase in deliveries to Federal agencies during the past seven years.

Fiscal year	Kilowatt hours	Percentage of total sales
1956	30,512,000,000	57
1955	21,770,000,000	52
1954	11,800,000,000	39
1953	6,967,000,000	29
1952	4,918,000,000	24
1951	2,191,000,000	13
1950	1,969,000,000	14

Most of the power delivered to the Federal agencies came from facilities placed in operation through the extraordinary construction programme carried on since 1951. At that time, the Korean War and the threat of a new world conflict dictated the beginning of a rapid expansion by the Atomic Energy Commission of atomic defence facilities in the Tennessee Valley region. The demand for power from the T.V.A. expanded correspondingly, and the Authority undertook the necessary construction of power supply facilities.

The total input to the T.V.A. system in the fiscal year 1956 was a little over 59,600 million kWh : 14,400 million kWh was generated by hydro-electric plants, and the T.V.A. steam power station produced 43,100 million kWh. Because of dry weather, hydro-electric generation was about 2000 million kWh less than that expected in a normal year. In addition, the Authority received about 2100 million kWh by purchase and interchange from other systems.

Several factors adversely affected the operations during the year, resulting in increased operating expense. Although nearly 1,500,000kW of generating capacity were added to the system, this was only about three-quarters of the total that had been scheduled. Because of strikes and other production difficulties at manufacturing works, three steam-electric generating units with a total capacity of nearly 600MW could not be placed in operation. Similar difficulties delayed the installation of three other units with a total capacity of more than 500MW. As a result, T.V.A. was deprived of a considerable amount of economical generation during the year. In addition, coal supplies were reduced in the autumn and winter by strikes, weather conditions, and other factors.

A severe drought that continued into the second half of the fiscal year also contributed to increased operating costs. At the beginning of the fiscal year, T.V.A. had water stored in its reservoirs equivalent to about 4100 million kWh, somewhat below normal. From July to November, the run-off from the watershed was at a level so low as to be expected only once in eight years, on the basis of long-term records. However, the use of stored water as planned in such an event forestalled the use of older, high-cost steam-electric plants or the curtailment of load during this period. In December, the stream-flows usually increase sharply, but this year the drought became worse. In the five weeks ended January 12, 1956, when less than 2in of rainfall may be expected only once in seventy-five years, the average rainfall for the Tennessee Basin was less than 1in. At the same time, cold weather brought higher demands for power.

During this period, the reservoirs were drawn to very low levels. In mid-January, all interruptible and supplemental power loads were cut back, in accordance with contract provisions. Most of the system's high-cost steam-electric power was put to use and additional power was purchased when available. These measures continued for a short time until the drought was broken near the end of the month. Heavy rainfall in February quickly brought most of the reservoirs back to normal levels for the season. In March water had to be spilled at the Norris, Wolf Creek and Watts Bar dams and all main river dams below Watts Bar to maintain storage space for flood control. The run-off was slightly above average the last quarter of the year. Reservoir filling after the major flood season brought storage to 5600 million kWh on May 13, equal to the highest of record ; at the close of the fiscal year 5100 million kWh was in storage. This was a gain of 1000 million kWh over that in storage at the beginning of the year.

The T.V.A. steam-electric generating stations operated at high efficiency during the year. The average annual heat rate of the T.V.A. system was 9780 B.Th.U. per kWh. In 1955, the rate was 10,062 B.Th.U. per kWh. The national average in the calendar year 1955 was 11,700 B.Th.U. per kWh generated. It is believed that the T.V.A. is the first major power system to achieve an average annual system heat rate of less than 10,000 B.Th.U. per kWh of net generation.

The steam power stations received 17,584,000 short tons of coal during the year, an increase of 46 per cent over the previous year. The total delivered cost was 76,600,000 dollars ; the average cost was 4·36 dollars a ton and 18·71 cents a million B.Th.U. The cost per B.Th.U. of coal delivered was about 3 per cent higher than the previous year, reflecting contract price adjustments for increases in miners' wages, a general tightening of the coal market conditions, some increases in freight rates, and temporarily high prices in the area around the Kingston station (Fig. 10), in East Tennessee. The statistics on fuel consumption at the major steam power stations are tabulated here.

Steam power station	Short tons of coal consumed	Cost in cents per million B.Th.U. consumed	B.Th.U. per kWh net generation	Cost in mills per kWh net generation
Colbert	2,320,662	19·11	9,413	1,799
Johnsonville	2,573,338	17·90	10,274	1,839
John Sevier	1,149,258	19·67	9,221	1,814
Kingston	4,290,072	19·59	9,637	1,888
Shawnee	4,481,292	17·08	9,792	1,672
Watts Bar	405,859	19·88	11,419	2,270
Widows Creek	2,366,904	19·51	9,846	1,921

(One mill=0·001 dollar.)

(*To be continued*)

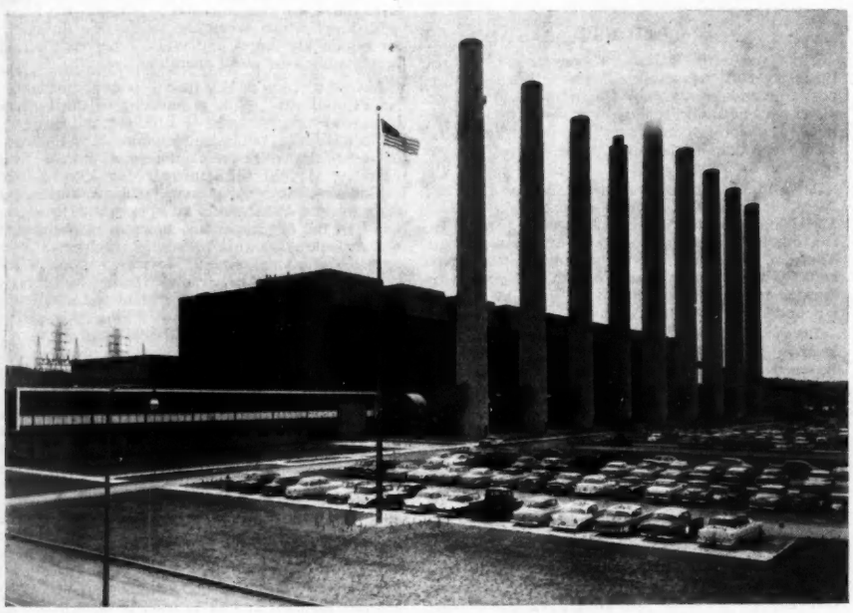


Fig. 10—Kingston steam power station which has nine turbo-generators of 1440MW total capacity

American Research Reactor for Brazil

The initial shipment of parts for a research reactor to be built in Brazil was recently made from the Port of New York. The components were destined for the first nuclear reactor to be built in a Latin-American nation, according to the Babcock and Wilcox Company, who designed and is fabricating the unit for the Institute of Nuclear Energy in Sao Paulo. The research reactor is the highest powered "pool" design reactor unit yet to be sent abroad from the United States. Rated at 5000kW of heat output, it will produce fifty times as much power as the pool reactor exhibited by the U.S. Atomic Energy Commission at the International Conference for the Peaceful Uses of Atomic Energy at Geneva in August, 1955. The reactor being supplied to Brazil is similar to the 1000kW pool research reactor recently supplied by the Babcock and Wilcox Company to the University of Michigan. It will be used by the faculty and students of the University of Sao Paulo for training and research. The fuel elements for the Brazilian reactor differ from similar fuel elements being used in the United States in that they contain uranium enriched to only 20 per cent of the Uranium–235 isotope. The elements will be manufactured especially for the Brazilian unit at the nuclear fuel fabricating facilities of Babcock and Wilcox, at Lynchburg, Virginia.

25,000MeV Particle Accelerator at Brookhaven National Laboratory

A particle accelerator which will be one of the most powerful in existence is being built at the Brookhaven National Laboratory, Long Island. This accelerator, which will be known as the A.G.S. (Alternating Gradient Synchrotron), will consist of a vacuum chamber in the form of a hollow steel and copper ring 842ft in diameter, enclosed in a similar ring shaped underground tunnel lined with reinforced concrete. The initial energy given to the particles (in this instance protons) will be derived from a 100ft long, 50MeV linear accelerator. Then the particles will be accelerated around the half-mile long vacuum chamber and will be constrained to move in circular orbits by 240 focusing magnets. Acceleration will be effected by twelve r.f. accelerating stations spaced around the vacuum chamber. After completing about 370,000 circuits within a second the protons will have acquired an energy corresponding to about 25,000MeV. The A.G.S. will give a pulse of 1000 million particles every three seconds. The installation is due to be completed in 1960 at a cost of 26,000,000 dollars and will include a power station with a 30MW generator to provide the necessary power supplies for the A.G.S.

Personal and Business

Appointments

MR. A. H. MASON has been appointed a director of B.S.A. Tools, Ltd.

MR. M. F. J. WRIGHT has been appointed advertising manager of Black and Decker, Ltd.

GRIFFIN AND GEORGE, Ltd., states that Mr. K. G. Sinclair has been appointed chairman.

MR. JAMES ALEXANDER LUMSDEN has been appointed a director of G. and J. Weir, Ltd.

MR. A. D. BARNSDALE has been appointed sales manager of Tappex Thread Inserts, Ltd., Warwick.

RHODEN PARTNERS, Ltd., states that Mr. B. W. Charman, A.M.I.Prod.E., has been appointed general manager.

MR. JOHN M. GRIFFITHS has been appointed senior area representative for the East Midlands of Whitlock Brothers, Ltd.

MR. S. A. CLODD, works manager, radio and television, has been appointed an executive director of E. K. Cole, Ltd.

THE CARRON COMPANY has announced the appointment of Mr. David Mackie as manager of the heavy engineering foundry.

MR. T. H. L. PARISH, formerly chief instructor of F. Perkins, Ltd.'s service school, has been appointed sales training manager.

BRITISH RAILWAYS, WESTERN REGION, has announced the appointment of Mr. A. W. McMurdo, A.M.I.C.E., as district engineer, Wolverhampton.

MR. F. H. ROBERTS has been appointed a director and chief engineer of John Thompson (Australia) Pty., Ltd., a member company of the John Thompson group.

LANGLEY ALLOYS, Ltd., has announced that Mr. B. Trehearne, A.I.M., has been appointed to develop a welding section for corrosion resistant copper and nickel base alloys.

MR. J. STATHAM has been appointed London area manager for Burton, Griffiths and Co., Ltd., and will be responsible for both the machine tools and small tools divisions.

LIEUT.-COLONEL G. J. W. TURNER, chairman of Wrights' Ropes, Ltd., and the Rollason Wire Company, Ltd., has been appointed High Sheriff of Warwickshire for 1957.

THE MINISTRY OF SUPPLY states that Mr. E. W. Chivers has been appointed deputy director of the Armament Research and Development Establishment, with effect from April 1.

THE BRITISH INDIA STEAM NAVIGATION COMPANY, Ltd., has announced the appointment of Captain Denys Robert Patrick Gun Cuninghame as Commodore Commander of its fleet.

THE MACHINE TOOL TRADES ASSOCIATION has announced that Mr. J. Cuthbert Robinson has been elected president of the Association for the year 1957–58, in succession to Mr. H. P. Potts.

MR. P. HOWDLE has been appointed publicity manager of Guy Motors, Ltd., in succession to Mr. R. J. Ridge, who has resigned to take up a similar position with the Coseley Engineering Company, Ltd.

KERRY'S (GREAT BRITAIN), Ltd., announces that Mr. M. S. Norton has been appointed general manager, sales, and Mr. H. T. Kemsley has been appointed general manager, branch administration.

Business Announcements

SIMMS MOTOR UNITS, Ltd., states that the registered trade name for its quick-action inertia starter is "Tensec."

RUSSELL CONSTRUCTIONS, Ltd., states that it is the sole selling agent for "Resilon," manufactured by Mendip Chemical Engineering, Ltd.

THE AUTOMATIC TELEPHONE AND ELECTRIC COMPANY, Ltd., states that it has purchased the building, 39–87, Cheapside, Liverpool.

CROMPTON PARKINSON, Ltd., states that its Darlington Branch has moved to new premises at King Street, Darlington (telephone, Darlington 5285/6).

THE FAIREY AVIATION COMPANY, Ltd., states that on medical advice Mr. H. E. Chaplin has relinquished his appointment as chief designer. He has agreed to act as design consultant to the firm.

THE UNITED STEEL COMPANIES, Ltd., states that Mr. K. C. Lodge, commercial manager and secretary of Owen and Dyson, Ltd., Rotherham, is retiring on March 31, after forty-six years' service.

FOUNDRY SERVICES, Ltd., states that Mr. E. G. P. Hinds, overseas technical representative for the Benelux countries, has left for Portugal, where he is to make an intensive study of the foundry industry.

F. PERKINS, Ltd., Peterborough, states that its Australian company's new service school at Dandenong, recently started operation. Mr. R. Y. McGeachy has been appointed permanent instructor.

THE HAWKER SIDDELEY GROUP states that A. V. Roe Canada, Ltd., has acquired the company PSC Applied Research, Ltd., designers and manufacturers of electro-mechanical instruments and systems.

PRIESTMAN BROTHERS, Ltd., states that its new home, embodying sales office, parts store, service depot and excavator showroom, has now been completed. Its new address is Great West Road, Brentford, Middlesex (telephone, Ealing 6717/8).

THE CONSOLIDATED PNEUMATIC TOOL COMPANY, Ltd., has announced the formation of a new company under the title of the Consolidated Pneumatic Tool Company (India) Private, Ltd., which will operate in Bombay where new factory premises are to be constructed.

CREMER AND BREARLEY, consulting chemical engineers, state that Mr. George Brearley will leave the partnership on March 31, on his appointment as director and secretary of the Association of British Chemical Manufacturers. The remaining partners will continue the practice.

TEDDINGTON AIRCRAFT CONTROLS, Ltd., has announced that it has closed its London office at 51, Brompton Road, Knightsbridge, S.W.3, and that the technical liaison staff has been transferred to the company's office at Cheapside Chambers, Cheapside, Reading, Berks (telephone, Reading 3074). The advertising department will be transferred from Colnbrook Bypass, Hounslow, Middlesex, to the South Wales factory, Teddington Aircraft Controls, Ltd., Merthyr Tydfil (telephone, Merthyr Tydfil 666), as from March 31.

Contracts

THE GLOUCESTER RAILWAY CARRIAGE AND WAGON COMPANY, Ltd., has received from the British Transport Commission an order for twenty multiple-unit diesel two-car trains, required in connection with the railway modernisation plan. The trains are to be used in the Edinburgh district of the Scottish Region of British Railways.

THE HARLAND ENGINEERING COMPANY, Ltd., Alloa, Scotland, has received a contract, valued at £276,000, from the Central Electricity Authority, for four boiler feed pump groups for the new West Thurrock power station, to be built on the north bank of the Thames estuary. The sets consist of booster and boiler feed pumps with motors of 1650 h.p. and 6500 h.p. per set.

BIRWELCO, Ltd., Aston, Birmingham, has been awarded a contract for the supply of equipment to be used in the Esso butadiene plant at Fawley, Hants. The largest unit will consist of a Petro-Chem "Iso-Flow" furnace with a heat release of 192 million B.Th.U. per hour. Other items include three smaller heaters and a quantity of heat exchange equipment to be supplied by Brown Fintube Great Britain, Ltd. The value of the contract is approximately £250,000.

HUMPHREYS AND GLASGOW, Ltd., has received the order to build the reforming plant at the Southampton gasworks and the installation will consist of two sets of Onia-Gegi catalytic plant, each capable of producing 8,000,000 cubic feet of gas per day, including cold enrichment when reforming gases piped from Fawley Refinery. The plant will produce 4,000,000 cubic feet when gasifying heavy oil. Two sets of regenerative plant for the gasification of heavy oil are to be installed at the Newcastle Redheugh gasworks.

FAIREY AIR SURVEYS, Ltd., has received contracts from the Directorate of Colonial Surveys for the aerial survey of an area of 38,000 square miles in Tanganyika and Bechuanaland. The surveys are part of the British Government's colonial development scheme and will begin in mid-April; they should be completed by the end of July. The aircraft allotted to this operation is a specially-equipped Douglas "DC-3," with supercharged engines, allowing it to operate at heights up to 28,000ft, although the surveys are to be carried out at 20,000ft above ground level.

Miscellanea

PORTABLE AND EXTENDABLE SCREW CONVEYOR.—A screw conveyor suitable for handling many forms of granular materials, which is made by Opancol, Ltd., 3/4, Sherwood Street, London, W.1, is readily portable and can be extended from a basic length of 9ft up to 25ft. The screw is carried in a 4in diameter steel tube and can be driven by a ½ h.p. or 1 h.p. electric motor or a petrol engine according to the duty required. The complete basic 9ft unit with a ½ h.p. motor drive weighs only 68 lb, or, with the full extension, 92 lb. It is pointed out that these "Quicklift" conveyors can be used over a wide range of angles, from the horizontal almost to the vertical, and passed through relatively small orifices or windows to deliver materials into or from buildings.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—On March 12 D. H. Sword presented his paper, "Ship Repairing," before the Institution of Engineers and Shipbuilders in Scotland. The paper refers to the problem of the continual growth in the size of ships and its effect in determining the repair facilities that must be provided. Consideration is given to the layout of a repair yard and to the type of dry dock, and there are descriptions of typical repair jobs.

MOTOR VEHICLE MANUFACTURE.—Great Britain stood third among the main car and commercial vehicle producing countries in 1956, although more commercial vehicles were built than in Western Germany (U.K., 298,609; Germany, 227,790). The totals for twelve months were: United States of America, 6,920,590; Western Germany, 1,075,619; United Kingdom, 1,006,203. No other country built over 1,000,000 vehicles, the fourth producer being France with 827,032.

NAVAL INTERCEPTOR.—The de Havilland "Sea Vixen" all-weather fighter for the Royal Navy, the D.H.110, flew for the first time in its developed form, prepared for the practical requirements of aircraft-carrier operation, last week. The swept wing is now provided with power folding, the radome nose is hinged for easy handling and maintenance, the nose-wheel is steerable for manœuvrability on deck, undercarriage legs have a longer stroke, the tailboom angle is modified for greater ground clearance, the wheel-well doors retract when the wheels are down, the air brakes are larger and many other details have been modified for naval operation.

MANUFACTURER'S MACHINE TOOL EXHIBITION.—An exhibition of about a hundred of the machine tools made and marketed by B. Elliott and Co., Ltd., Victoria Works, Willesden, London, N.W.10, are to be demonstrated at an exhibition in Bristol, from Monday, May 20, till Saturday, May 25 next. The exhibition is designed primarily to give engineering firms in the West Country an opportunity to see the latest of the organiser's machines in operation. It will include "Victoria" milling machines, "Progress" drilling machines, "Invicta" and "Alba" shapers, "Cardiff" lathes, and "Excel" grinders, as well as a wide selection of other plant and engineering equipment.

THE INSTITUTE OF MARINE ENGINEERS.—A paper entitled "The Harland and Wolff Pressure Charged Two-stroke, Single-acting Engine," was read before the Institute of Marine Engineers on March 12. The paper gives a description of the Harland and Wolff opposed-piston, pressure charged engine and deals with the various components in detail. The engine parts are divided into static and running components and in each instance particulars are recorded of dimensions, material used and design, all of which are illustrated by line drawings, while graphs indicate such items as bearing loads, engine balancing, turning moments and guide shoe thrust loads. A section of the paper examines exhaust turbo-charger arrangements, including six and eight-cylinder systems, and the results of tests which are set out in graphical and tabular form.

IMPROVEMENT OF RIVER TRENT NAVIGATION.—Sir Brian Robertson, Chairman of the British Transport Commission, announced at Nottingham on March 8 that the Commission has approved a £473,000 programme of further improvements on the River Trent. The programme forms part of the Commission's £5,500,000 development plan for the principal inland waterways. The work now to be undertaken on the Navigation comprises: bank protection and navigation works, £216,500; extension of Cromwell Lock, £27,000; mechanisation of lock gates and sluices, £38,000; dredging and other plant, £169,500; workshops and other premises, £22,000. The piling works, in addition to bank protections, include strengthening some of the main weirs by steel piling and concreting. The work will be preceded by experiments to be undertaken by the Commission's Research Officer. The existing Cromwell Lock, some 5 miles downstream from Newark, although 30ft wide and able to accommodate four standard Trent barges or one large oil tanker, is not sufficiently deep to pass craft through at all tides; and at neap tides craft can pass into the lock only by using a third pair of shallow gates built below the main lock tail to form a "two rise" lock. It is now proposed to replace the third pair of tidal gates with deep gates extending up to coping level.

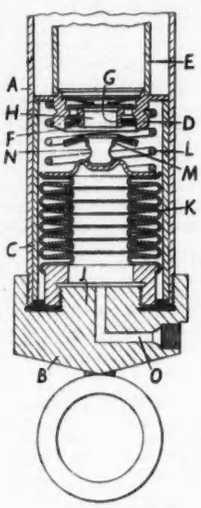
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

HYDRAULIC MACHINERY

767,551. November 8, 1954.—HYDRAULIC SHOCK ABSORBERS, Eric Cookson, 14, Wilkinson Avenue, Blackpool, Lancashire.

The invention relates to dampers or shock absorbers of the type in which fluid is expelled by a piston into a reservoir tube, with the object of making the compression-resistance characteristics variable in use. From the drawing it will be seen that the usual reservoir tube *A* of the shock absorber is extended at the bottom and screws into a base fitting *B*. Over its extension there is provided a liner *C*, which at its upper end supports a base *D* fitting into the end of the pressure tube *E*, and contains a pressure valve with an outer resistance passage *F* formed between the member *D*, an inner spigot ring *G*, and an inner recuperating or pressure intake valve passage *H* lying within the ring. The inner end of the base *B* has a central raised portion *J* in which screws a metal or rubber bellows capsule *K*. This capsule is compressed by a spring *L* above. To the top of the capsule is secured a member *M* having an upper coned part, with a rubber face, and which when the bellows is extended, closes the passage *F*. The centre part of the member *M* is open and free



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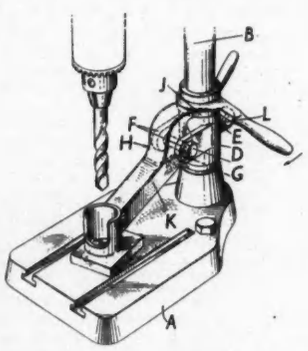
passage of fluid is provided through the side wall apertures *N*. The base *B* has an inlet passage *O* for connection to a hydraulic fluid supply. In operation if the pressure of fluid supplied through this passage is increased sufficiently the resistance valve passage way *F* will not be opened again until the pressure of the hydraulic fluid within the pressure tube *E* has increased to a sufficient value to depress the member *M* against the pressure of the hydraulic fluid within the bellows capsule *K*.—*February* 6, 1957.

WORKSHOP TOOLS AND APPLIANCES

769,004. November 13, 1953.—DEVICE FOR HOLDING DOWN WORK ON DRILLING MACHINES, John Harding Taylor, Bunker Hill, Medomsley, County Durham.

Referring to the drawing, the drilling machine comprises a work table *A* from which rises a pillar *B* carrying the drilling head. *D* is a bracket which comprises a relatively deep split collar adapted to pass over the pillar, on the one side of which collar are lugs *E* for clamping the collar about the pillar at the desired height. On the opposite side extend a pair of rigid arms *F*, between which is mounted about



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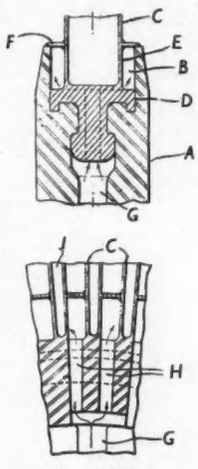
a bolt *G* a lever *H* whose arms are substantially at right angles. The one lever arm is relatively short, and is shaped to abut against a horizontal peripheral cam face *J* on a cam member rotatably mounted on the pillar and resting on the upper side of the collar *D*. The other lever arm *K* extends at a slight downwards angle so as to terminate just short of the drilling spindle axis; and rigid with this end is a vertical hollow cylindrical foot or heel having its lower face serrated to effect a grip on the workpiece. On the lower face of the long arm *K* is an abutment and a corresponding abutment is formed on the collar. Between these two abutments there is inserted a compression spring which tends to maintain the cam arm in contact with the cam face *J*. The rotatable cam member has rigidly mounted a handle. The clamping of the collar to the pillar is effected by means of a quick release nut on the usual clamping bolt *L* which passes through the lugs on the collar. In use, with the collar *D* clamped at a height depending on the thickness of the workpiece, and the cam member *K* swung back, the workpiece is inserted under the heel. The cam arm is then swung round so that the clamping lever *H* is pressed down, and the workpiece is held firmly.—*February* 27, 1957.

GAS TURBINES

767,800. May 20, 1952.—MEANS FOR COOLING GAS TURBINES, Denis Crichton Maxwell, K.C.B., C.B.E., Vice-Admiral (E), Engineer-in-Chief of the Fleet, of Admiralty, London, S.W.1, and The Parsons and Marine Engineering Turbine Research and Development Association, of Pametrada Research Station, Wallsend-on-Tyne. (*Inventors: Basil Joseph Terrell* and *Frederick John Bayley.*)

The invention relates to means for cooling gas turbines, particularly turbines operating with gas temperatures in excess of 1200 deg. Fah., and its object is to provide means whereby liquid cooling mediums may be utilised to the best advantage. Referring to the drawing a turbine disc *A* is channelled inwards from its outer periphery so as to form an annular channel *B*. The disc has blades such as *C* having an inverted T-root fixing *D* seated on the bottom or inner periphery of the channel *B* which surrounds a part *E* of the blade additional to its effective length or span in way of the hot gases. A cap or collar *F* is inserted over the blades and is welded thereto and to the outer periphery of the disc thereby sealing the channel *B*. As shown in the upper and lower views, a path for liquid coolant into the annular channel *B* is formed by a radial passage *G* and two radial passages *H* in the disc and in two adjacent blade roots respectively. Arrowheads are inserted in the drawing to show the direction of flow of coolant. It will be seen that coolant from the passage *G* in the disc *A* divides into two streams which flow through the passages *H* in the two adjacent blade roots, into the channel *B*, wherein the flow is maintained in two separate streams which are constrained to flow circumferentially in the opposite directions by means of baffles fitted on each side of a blade, as shown, so as to bridge the channel. Other baffles are arranged to bridge the annular passage *B* on one side only so that the coolant is made to traverse the blade twice, with the advantage previously referred to. The blades in this example are hollow, having cavities *J* in which a heat transfer medium, for example water, is enclosed. A four stage turbine fitted with cooled blades is also shown in the specification.—*February* 6, 1957.



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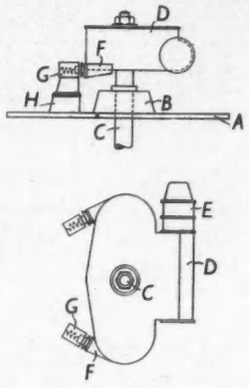
MARINE ENGINEERING

769,034. September 30, 1954.—MARINE RUDDER INSTALLATIONS, Siemens-Schuckertwerke Aktiengesellschaft, Berlin and Erlangen, Germany, and Max Mörck, Hamburg, 39, Jarrestrasse, trading under the name of Schaffe and Co., Hamburg, Germany.

Although the known rudder installations may be assembled with great care in order that the transmission pinion and quadrant mesh satisfactorily, yet difficulties still occur if the bedplate for the rudder gearing is insufficiently strong or if the stern is too weak so that deflection of the teeth, that is to say heavy wear, takes place. It is an object of the invention to overcome these disadvantages. Referring to the drawing, resting upon a bedplate *A* is a bearing *B* in which a rudder stock *C* is mounted. The stock has mounted on it a transmission means *D* to which there is secured a driving motor *E* which is constructed as a normal flange-mounted electric motor. The transmission means is provided with stops *F* for the substantial prevention of rotation of the transmission means. However, the stops bear against spring buffers



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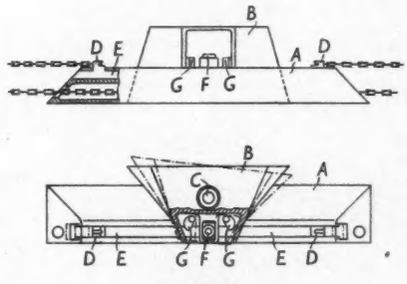
G which permit some rotation of the transmission device to thereby absorb any momentum of the stock. The spring buffers *G* bear against the bedplate *A* through the medium of supports *H*.—*February* 27, 1957.

MINING ENGINEERING

769,328. May 28, 1954.—MINERAL MINING MACHINE, Deutsche Kohlenbergbau-Leitung, 2, Friedrichstrasse, Essen, Westphalia, Germany.

The invention relates to machines for mining minerals, especially coal, from a seam by planing it from the face of the seam. As shown in the drawing, on the main body *A* of the machine a knife-carrying member *B* is mounted, being pivotable within limits about a pivot *C*. The haulage means comprise a single chain, the opposite ends of which are attached to hooks *D* on a bar *E*, slidable within limits in the body of the machine in the direction along the seam. The haulage chain runs from one hook *D* to direction-changing means, back through an aperture in the body of the machine, around further direction-changing means, and back to the other hook. The knife-carrying member *B* has an extension in the direction outwards from the seam face, through which passes a rectangular aperture, and a block slides within the rectangular aperture either towards or away from the pivot *C*. The block is connected to bar *E* by a pin *F* about which it can revolve. Stops



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G are provided which limit the pivoting of the knife-carrying member *B* about the pivot. Since bar *E* is linked, through the block with member *B*, stops *G* also limit the sliding motion of the bar. When, at the start of a run along the seam face, the haulage chain is put under tension, first bar *E* slides within the body in the direction in which the machine is about to move, and through the pin and block pivots knife-carrying member *B* until the motion is limited by one of the stops *G*. The leading knife will then be in its operative cutting position. When member *B* is against a stop the bar will also be prevented from further sliding within body *A* and so, as the tension in the haulage chain continues, the whole machine will move along the seam. According to a further feature of the invention, means may be provided whereby the limiting positions to which the knife-carrying member can pivot are made adjustable, either continuously or discontinuously, and hence the depth of penetration of the leading knife into the seam, and the thickness of the section of mineral planed from the seam, are adjustable.—*March* 6, 1957.

Catalogues and Brochures

MEGATOR PUMPS AND COMPRESSORS, Ltd., 43, Berkeley Square, London, W.1.—Illustrated brochure describing mining pumps for face drainage, dust suppression and wet cutting and the larger "GH" type pumps with capacities up to 160 g.p.m., and heads up to 350ft. Tables are included giving output details together with relative weights and dimensions.

FERRANTI, Ltd., Hollinwood, Lancs.—Brochure No. IS.6, describing various methods of summation and summation metering equipment, for providing individual meter readings, combined readings and combined demands at one central point. Provision is also made for reading the maximum demand for all circuits with allowance for load diversity factor.

BRITISH TIMKEN, Ltd., Duston, Northampton. Booklet for distribution to universities, technical colleges, schools, appointments boards, and other educational and personnel bodies. Details are given of the organisation's training schemes for craft, student, technical, graduate and female apprentices, together with notes on subsequent careers and opportunities.

EVANS ELECTROSELENIUM, Ltd., Harlow, Essex.—Illustrated leaflet giving details of the "Unigalvo" galvanometer. This unit can be supplied in two types: Type 15, current or voltage measuring unit with range switch and terminals; Type 20, current measuring unit with stabilised power supply to facilitate the use of external photo-electric measuring instruments.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Nobel Division, 25, Bothwell Street, Glasgow, C.2.—Booklet entitled "Silicones for Foam Prevention," describing anti-foam agents for the suppression or prevention of foaming in a variety of industrial processes. Silicone anti-foam agents are non-toxic and may be used safely in food-processing industries. These agents are also non-polar and do not associate with organic materials or water. Illustrated examples are given in this booklet of some of the processes where silicone anti-foam agents are effective.

HILGER AND WATTS, Ltd., 98, St. Pancras Way, Camden Road, London, N.W.1.—Catalogues giving technical details and photographs of a range of apparatus for emission spectrochemical analysis. Catalogue No. CH401 is a general introduction to spectrochemical analysis. No. CH402 deals with source units and electrode-holders. No. CH403 describes photographic spectrographs, including prism and grating instruments. No. CH404 is concerned with interpretation equipment. No. CH405 gives details of direct-reading spectrographs.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF MINING ELECTRICAL AND MECHANICAL ENGINEERS

Tues., April 2.—21, Bloomsbury Street, London, W.C.1, "The Past, Present and Future of Coal Preparation," A. Grounds, 6.15 p.m.

ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX

To-day, March 29.—Royal Society of Arts, 8, John Adam Street, Adelphi, London, W.C.2, "The Reorganisation of a Special Library," H. C. Richardson, 6 p.m.

Wed., April 3.—Industrial Welfare Society, 48, Bryanston Square, London, W.1, "The Availability of Atomic Energy Information," R. M. Fishenden, and "The Needs of Librarians in Relation to Atomic Energy Information," Miss J. Binns, 2 p.m.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., April 1.—BOLTON BRANCH: Balmoral Hotel, Bradshawgate, Bolton, "1956 Electrical Engineers' Exhibition," Film, 7.30 p.m. ★ LEEDS BRANCH: Great Northern Hotel, Leeds, "Kopp Variators," J. A. Horne, 7.30 p.m. ★ N.E. LONDON BRANCH: Angel Hotel, Ilford, "Timber Extraction in West Africa," D. Allan, 7.30 p.m. ★ SHEFFIELD BRANCH: Royal Victoria Station Hotel, Sheffield, "Lighting in Crime Detection," 7.30 p.m.

Tues., April 2.—LUTON BRANCH: Chamber of Commerce, George Street West, Luton, "Physical Aspects of Electricity," S. J. Emerson, 8 p.m. ★ OXFORD, READING AND DISTRICTS BRANCH: Palmer Hall, West Street, Reading, "Lighting Specification, Design and Planning," W. Imrie-Smith, 7.15 p.m. ★ TYNESIDE BRANCH: Crown Hotel, Newcastle upon Tyne, "Earthing and Earth Leakage Protection," J. A. Robbins, 7.30 p.m. ★ W. LONDON BRANCH: Windsor Castle Hotel, 134, King Street, Hammersmith, London, W.6, "Diesel Engines," J. C. Barber, 7.30 p.m.

Wed., April 3.—GLASGOW BRANCH: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Manufacture of H.V. and L.V. Cables and their Uses," 8 p.m. ★ MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Television as an Aid to Industry," 7.30 p.m. ★ N. LONDON BRANCH: "Queen's Head," 677, Green Lanes, Harringay, London, N.4, "Safe Use of Electricity," S. J. Emerson, 7.45 p.m. ★ PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "Supervisory Remote Control and Telemetering Systems," D. A. Brett, 7.30 p.m.

Thurs., April 4.—S. LONDON BRANCH: Half Moon Hotel, Broad Green, Croydon, "Relay Control," 8 p.m.

Fri., April 5.—LIVERPOOL BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Servicing the Automobile Electrical Equipment," 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., April 4.—N.W. SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, "Electronic Control of Machine Tools," H. Ogden, 6.30 p.m. ★ SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Telemetry," A. Cowie, 7 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., April 6.—Caxton Hall, Caxton Street, London, S.W.1, "History of Rocket Development in the Walterwerke," Heinz Walder, 6 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., April 2.—Hull Church Institute, Hull, Annual General Meeting, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., April 3.—EDINBURGH CENTRE: Y.M.C.A., 14, South St. Andrew Street, Edinburgh, Annual General Meeting, 6.15 p.m. ★ NEWCASTLE UPON TYNE CENTRE: Grey Hall, Department of Electrical Engineering, King's College, College Road, Newcastle upon Tyne, Annual General Meeting, 6.15 p.m.

Thurs., April 4.—NOTTINGHAM CENTRE: Electricity Service Centre, Smithy Row, Nottingham, "The Architect and the I.E.S. Code," A. Buchanan Cambell, 5.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, March 29.—MOBILE PLANT GROUP: Imperial Hotel, Temple Street, Birmingham, Discussion on "Torque Convertors," 7.30 p.m.

Tues., April 2.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Applications of Plastics in Industry," C. L. Child, 7 p.m. ★ EDINBURGH BRANCH: Heriot-Watt College, "The Generation and Use o Steam," 7 p.m.

Wed., April 3.—S. BRANCH: Grand Hotel, Bournemouth, "Industrial Diseases," K. Biden-Steele, 7.30 p.m.

INSTITUTE OF FUEL

Wed., April 3.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Experiments Concerning the Effect of Coking Pressure in Full-Scale Operation of Coke Oven Plant," J. L. Lambert, W. J. Lancucki-Pater and G. W. Lee, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, March 29.—MERSEYSIDE AND N.W. SECTION: College of Technology, Byrom Street, Liverpool, "The Control of Steam Temperature in Marine Watertube Boilers," E. G. Hutchings, 7 p.m.

Mon., April 1.—MERSEYSIDE AND N.W. SECTION: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Practical Application of the 1952 Fire Appliance Rules," G. Keenan, 6.30 p.m.

INSTITUTE OF METALS

Tues., April 2.—OXFORD LOCAL SECTION: Cadena Cafe, Cornmarket Street, Oxford, "Fatigue," N. Thompson, 7 p.m.

Thurs., April 4.—LONDON LOCAL SECTION: 17, Belgrave Square, London, S.W.1, "Recent Developments in Electron Microscopy," J. Nutting, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., April 3.—26, Portland Place, London, W.1, "Some Applications of Radioactivity in the Petroleum Industry," J. L. Putman, 5.30 p.m.

INSTITUTE OF PHYSICS

Fri. to Sat., April 5 *to* 6.—X-RAY ANALYSIS GROUP: Physics Department, University College, Cardiff, Spring Conference, "Minerals and Inorganic Compounds."

INSTITUTE OF REFRIGERATION

Thurs., April 4.—Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Rapid Cooling of Meat in Germany," J. Kuprianoff, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., April 2.—E. CENTRE: Lion Hotel, Cambridge, Annual General Meeting, 7.30 p.m.

Wed., April 3.—W. CENTRE: Angel Hotel, Bath, Annual General Meeting, 7 p.m. ★ E. MIDLANDS CENTRE: Mechanics' Institute, Nottingham, "Some Aspects of Vehicle Insurance and Accident Assessment," A. G. Wright, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., April 2.—Royal Institution, Albemarle Street, London, W.1, "The Aqueous Homogeneous Reactor," R. Hurst, 5.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., April 2.—MARITIME AND WATERWAYS: Great George Street, Westminster, London, S.W.1, "Design and Construction of the Apapa Wharf Extension, Lagos," D. C. Coode, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, March 29.—S. CENTRE: S. Dorset Technical College, Weymouth, "Nuclear Power," H. A. Roberts, 6.30 p.m.

Mon., April 1.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, Informal Evening, "Colour Television," L. C. Jesty and E. L. C. White, 5.30 p.m. ★ MERSEY AND N. WALES CENTRE: Liverpool Royal Institution, Colquitt Street, Liverpool, "The Potentialities of Railway Electrification at the Standard Frequency," E. L. E. Wheatcroft and H. H. C. Barton, 6.30 p.m. ★ S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, Joint Meeting with the Supply and Utilization Group, "The Pimlico District Heating Undertaking: Costs and Financial Results," B. Donkin, C. M. Johnston and E. Ockenden, 6 p.m. ★ N.E. RADIO AND MEASUREMENTS GROUP: King's College, Newcastle upon Tyne, "The B.B.C. Sound Broadcasting Service on Very-High Frequencies," E. W. Hayes and H. Page, 6.15 p.m. ★ S. MIDLAND SUPPLY AND UTILIZATION GROUP: James Watt Memorial Institute, Great Charles Street, Birmingham, Joint Meeting with the S. Midland Centre, "The Pimlico District Heating Undertaking: Costs and Financial Results," B. Donkin, C. M. Johnston and E. Ockenden, 6 p.m.

Tues., April 2.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "The Teaching of Electrical Installation Subjects," opened by R. W. G. Ward, 6 p.m. ★ N. MIDLAND CENTRE: Royal Station Hotel, York, "The Potentialities of Railway Electrification at the Standard Frequency," E. L. E. Wheatcroft and H. H. C. Barton, 7 p.m. ★ S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "Choice of Insulation and Surge Protection on Overhead Lines of 33kV and Above," A. Morris Thomas and D. F. Oakeshott, 7 p.m. ★ E. MIDLAND CENTRE: Loughborough College, Loughborough, "Power Amplifiers Used in Automatic Control," J. V. Parry, 6.30 p.m. ★ N.E. CENTRE: City Hall, Newcastle upon Tyne, "Nuclear Energy in the Service of Man," T. E. Allibone, 7 p.m. ★ N.W. CENTRE: Engineers' Club, 17, Albert Square, Manchester, "Earth Electrode Systems for Large Electric Stations," J. D. Humphries, 6.15 p.m.

Wed., April 3.—LONDON GRADUATE AND STUDENT SECTION: Savoy Place, London, W.C.2, "Electric Breakdown in Gases," A. E. D. Heylen, 6.30 p.m. ★ TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "The Measurement of Earth-Loop Resistance," G. F. Tagg, 6.30 p.m. ★ S. CENTRE: Portsmouth College of Technology Extension, Anglesea Road, Portsmouth, "The Human Operator in Closed Loop Control Systems," C. Holt Smith, 6.30 p.m.

Thurs., April 4.—ORDINARY MEETING: Savoy Place, London, W.C.2, Forty-Eighth Kelvin Lecture on "Infra-Red Radiation," G. B. B. M. Sutherland, 5.30 p.m. ★ S.W. SUB-CENTRE: Electric Hall, Torquay, "Television Interference," P. W. Crouch, 3 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Wed., April 3.—Queen's Hotel, Birmingham, "Turbo-Car Progress," P. A. Phillips, 7.46 p.m.

Thurs., April 4.—36, Portland Place, London, W.1, "The Training of Engineering Draughtsmen and Designers," C. Waldron, 6.45 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Wed., April 3.—E. MIDLANDS BRANCH: Grand Hotel, Leicester, Annual General Meeting, 6.45 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., April 5.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Improvement of Traffic Flow in Urban Areas," S. Green, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 29.—GENERAL MEETING IN CONJUNCTION WITH THE LUBRICATION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Rotary Shaft Seals: The Sealing Mechanism of Synthetic Rubber Seals Running at Atmospheric Pressure," E. T. Jagger, 6 p.m.

Tues., April 2.—EDUCATION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Need for Technologists in the Next Ten Years and How it is Likely to be Met," 6.45 p.m. ★ N.E. BRANCH: Cleveland Scientific and Technical Institution, Middlesbrough, "The Economics of Plant Renewal and Replacement," C. W. Griffiths, 6.15 p.m.

Wed., April 3.—E. MIDLANDS BRANCH: College of Technology, Chesterfield, Joint Meeting with the Yorkshire Branch, "The Rival Rail Traction Systems," J. W. Caldwell, 7.30 p.m. ★ YORKSHIRE BRANCH: Technical College, Chesterfield, Joint Meeting with the E. Midlands Branch, "The Rival Rail Traction Systems," J. W. Caldwell, 7.30 p.m.

Thurs., April 4.—N.E. BRANCH: Stephenson Building, Claremont Road, Newcastle upon Tyne, "Crankcase Explosions: An Investigation Governing the Selection of Protective Devices," H. G. Freeston, J. D. Roberts and A. Thomas, 6.15 p.m. ★ E. MIDLANDS GRADUATE SECTION: College of Technology and Commerce, Leicester, "Nuclear Power: Basic Principles and Their Applications," J. Diamond, 7.15 p.m. ★ YORKSHIRE GRADUATE SECTION: Mining Lecture Theatre, University, St. George's Square, Sheffield, Discussion Evening, 6.30 p.m.

Fri., April 5.—GENERAL MEETING IN CONJUNCTION WITH THE HYDRAULICS GROUPS: 1, Birdcage Walk, Westminster, London, S.W.1, "Modern Trends in Waterworks Pumping Machinery," T. Irvine Hudson, 6 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., April 2.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Corrosion of Underground Telecommunication Cables," J. Gerrard and J. R. Walters, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Sat., March 30.—N.E. GRADUATE SECTION: Visit to Vickers-Armstrongs, Ltd., Tractor Division, Scotwood, Newcastle, 10 a.m.

Tues., April 2.—COVENTRY GRADUATE SECTION: Craven Arms, High Street, Coventry, Annual General Meeting, 7.15 p.m.

Wed., April 3.—DUNDEE SECTION: New Imperial Hotel, 15, Tally Street, Dundee, "Automatic Control of Machine Tools," A. G. Barton, 7.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Fri., April 5.—N.E. SECTION: Eldon Grill, Grey Street, Newcastle, Annual General Meeting, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Mon., April 1.—LONDON GRADUATES' AND STUDENTS' SECTION: 11, Upper Belgrave Street, London, S.W.1, Annual General Meeting and Films on "Bridging the Golden Gate" and "The Construction of Little Aden Oil Harbour," 6.30 p.m.

Tues., April 2.—N. IRELAND BRANCH: College of Technology, Belfast, Film Evening, 6.45 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 29.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Making Use of Russian and Czech Scientific and Technical Information," E. Gros, 7 p.m.

Wed., April 3.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Planning and Organisation of Capital Projects," G. F. Wilkinson, 7 p.m.

Fri., April 5.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., April 3.—24, Dale Street, Liverpool, "Engineering Works at the Port of Liverpool," R. A. Stephenson, 6 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, March 29.—Engineers' Club, Albert Square, Manchester, "Nuclear Engineering," J. Diamond, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Mon., April 1.—Lecture Theatre, Mining Institute, Newcastle upon Tyne, "Graphical Presentation of Hull Frequency Data and the Influence of Deck-Houses on Frequency Predictions," A. J. Johnson and P. W. Ayling, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., April 2.—MIDLAND COUNTIES BRANCH: Birmingham and Midland Institute, Paradise Street, Birmingham, "Concrete Construction in the Soviet Union," L. J. Murdock, W. J. Beckwith, D. D. Matthews and K. M. Wood, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., April 4.—MAIN LECTURE: Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Engine-Airframe Integration," L. F. Nicholson, 6 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Sat., March 30.—Houldsworth Hall, Manchester, "The Application of Town and Country Planning to the Coal Mining Industry, with particular reference to a New Colliery," R. C. Wright, 10.30 a.m.

Mon., April 1.—ORDINARY MEETING: 12, Great George Street, London, S.W.1, "Capital Investment in Agricultural Land," E. S. Dobb, 5.45 p.m.

ROYAL METEOROLOGICAL SOCIETY

Wed., April 3.—SYMONS MEMORIAL LECTURE: 49, Cromwell Road, London, S.W.7, "Experiments at High Altitudes with Free Balloons," C. F. Powell and Melville Wills, 5 p.m.

ROYAL SOCIETY OF ARTS

Wed., April 3.—John Adam Street, Adelphi, London, W.C.2, "Spherical Perspective," J. L. P. Macnair, 2.30 p.m.

ROYAL SOCIETY OF HEALTH

Wed., April 3.—LONDON SESSIONAL MEETING: 90, Buckingham Palace Road, London, S.W.1, "Lung Cancer and Smoking," Richard Doll, 2.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Tues., April 2.—CHEMICAL ENGINEERING GROUP: 14, Belgrave Square, London, S.W.1, "Some Applications of Statistical Control to the Chemical Industry," A. G. Baker, 5.30 p.m.

Wed., April 3.—CORROSION GROUP: Technical College, Newport, Monmouthshire, "The Protection of Structural Steel Against Corrosion," J. C. Hudson, 7 p.m.

SOCIETY OF ENGINEERS

Mon., April 1.—ORDINARY MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, "Automation in the Motor Car Industry," N. F. Maylin, 5.30 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Thurs., April 4.—INFORMAL MEETING: National College of Horology and Instrument Technology, Northampton Polytechnic, St. John Street, London, E.C.1, Discussion on "Education," opened by C. J. Charnley and S. W. J. Wallis, 6.30 p.m.

WOMEN'S ENGINEERING SOCIETY

Fri., April 5.—LONDON BRANCH: Hope House, 45, Great Peter Street, London, S.W.1, "The Use of Electronic Computers in Engineering," Miss Jill Robinson, 7 p.m.

Advanced Engineering Courses

Chemical and Engineering Problems in Industrial Processes. THE COLLEGE OF TECHNOLOGY, Davy House, Ashley Down, Bristol, 7. Two-day course, Friday and Saturday, April 26 and 27. Fee £2 2s.